Government of Bengal

Public Health Department

# Malaria and Agriculture in Bengal

## How to Reduce Malaria in Bengal by Irrigation

by

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## PREFACE.

The following report on malaria in relation to the agricultural conditions of Bengal is submitted for the information of the Government of Bengal.

CHAS. A. BENTLEY.

CALCUTTA,
WRITERS' BUILDINGS

*The 20th March 1925.*

# MALARIA AND AGRICULTURE IN BENGAL.

## TABLE OF CONTENTS.

# Malaria and Agriculture in Bengal.

## INTRODUCTION.

### Malaria and Agriculture.

"Only the greatest wilderness or the most complete culture of the land protects a district from malaria."

ASCHENFELDT.

"The neglect of cultivation of the soil and the decay of land recently built on are conducive to malaria, whereas, on the contrary, a rational culture of the soil causes the gradual disappearance of malaria."

SCHEUBE.

"Experience teaches that the soil is the more insalubrious the less it is cultivated. In the cultivation of the soil, we include several factors, namely, the regulation of the ground moisture by canalisation, drainage, etc., the growing of plants, which, by using up the water, contribute to the drying of the soil, and finally, the number of the population, etc."

MANNABERG.

#### 1.—Malaria and Agricultural Decline.

A close association has always been recognised between malaria and agricultural conditions, and it has long been known that a greatly increased prevalence of the disease almost invariably accompanies the decay of agriculture and the decline of cultivation. For example, Pliny, in his Natural History, writing of malaria in ancient Italy, records that :

"The Pontine marshes were anciently a fertile and well-cultivated plain occupied by twenty-four villages, but towards the close of the republic gradually fell into their present condition, *owing to the decline of agriculture.*"

A similar explanation has been given of the increase of malaria in the Tuscan Maremma ;

"During the Etruscan period, it possessed several considerable towns, but *on the decline of agriculture* in Italy and the conversion of the farms into pasture lands, the desolation of the coast districts made rapid progress."

Of the Roman Campagna also, it is stated :—

"Once a densely-peopled land with numerous and prosperous towns, it is now a dreary waste, of which barely one-tenth part is furrowed by the plough share. In May, when malaria begins to prevail, herdsmen and cattle retire to the mountains; while the few individuals, who are compelled to remain behind, lead a miserable and fever-stricken existence. The cause of this change dates from as remote a period as the last centuries of the republic, when the independent agricultural population was gradually displaced by proprietors of the large estates and pastures. This system inevitably entailed the ruin of the country, for a dense population and a high degree of culture alone can avert the malaria which is produced by defective drainage and the collection of stagnant water in the undulating and furrowed volcanic soil."

2. The great epidemic of malaria in Mauritius and Reunion in 1867 followed a deterioration of agriculture. Hirsch points out, when describing this outbreak, that—

"The coast and level country of the Mauritius, which formerly afforded a rich soil for the growing of coffee, indigo and cotton, had been gradually allowed to go out of cultivation and had become entirely barren."

"Mauritius is over-drained," says one of the reports on the epidemic, "the localities which are the driest, and where health and agriculture suffer most, being low lands on the eastern, north-western and northern coasts." . . . .

"Meanwhile, the yield of sugar estates on and near the eastern, north-western and northern coasts began to decline and, their unproductiveness continuing to increase, some of them were at length abandoned. Since 1864 or 1865, about 35 sugar houses on the low land have been closed and extensive plains, which at one time were highly fertile, are now barren. The present sterility of these lands is generally ascribed to want of sufficient moisture. It is said that, owing to the clearings which have been made on the elevated lands to windward, the soil and air on the low lands to leeward have become too hot and above all too dry for sugarcane. Others again, while not disputing that *déboisement* on the high land has produced injurious effects on the low lands, consider that the principal cause of the sterility is exhaustion of that soil induced by long continued cultivation of the same plant."

3. Hirsch associated the increase of malaria in Georgia (U. S. A.) with very similar conditions :—

"In Georgia, the disease prevails widely and in severe forms, not only in the numerous creeks of the coast, but also in the interior, the neglect of agriculture having greatly conduced in quite recent times, as it seems, to an increase both in the amount and intensity of endemic fever."

"There was waste land," says Winwood Reade, "in abundance at the South; but it was *dead*. Their style of agriculture was *precisely that which is pursued* in Central Africa. They took a tract from the wilderness and planted it again and again with cotton and tobacco till it gave up the ghost and would yield no more."

They then moved on and took in another piece. Obliged to spend all their cash in buying prime slaves at two hundred pounds a piece, they could not afford to use manure or to rotate their crops. . . . . The Northerner, who travelled down South, was astonished to find that the cities of the maps were villages and the villages clusters of log huts. Fields covered with weeds and moss-grown ruins showed where farms once flourishing had been."

Norcom, writing in 1874 regarding the remarkable increase of malaria in the Southern States of the Union, remarks :—

"Before the war, the Southern States were in a high state of cultivation and the lands thoroughly drained; hence the malignant forms of malarial disease as a general rule were not known, except in very low, badly-drained swamp lands. Within the past eight years, owing to so much land lying waste, defective drainage and the general insanitary condition of the country, the malarial poison has acted with intense virulence and caused the disease we are now considering."

4. At a much later date, Laveran, when describing the malarious districts of France, states that :

"La Sologne florissante sous Henry IV était devenue au commencement de ce siècle, à la suite de l'abandon de la culture du sol, une des regions les plus misérables et les plus insalubres de la France."

5. The passages quoted above emphasize the overwhelming importance of cultivation of the soil in relation to malaria, and with good reason, for the question of rural malaria is so closely bound up with that of agriculture that the one cannot be properly understood without some knowledge of the other. Moreover, as will be shewn later there are grounds for believing that the mitigation and prevention of malaria in the rural districts of Bengal, a problem for which no adequate solution has yet been suggested, may eventually be secured by measures, designed as much for preserving or restoring agricultural prosperity as for directly dealing with malaria.

# CHAPTER I.

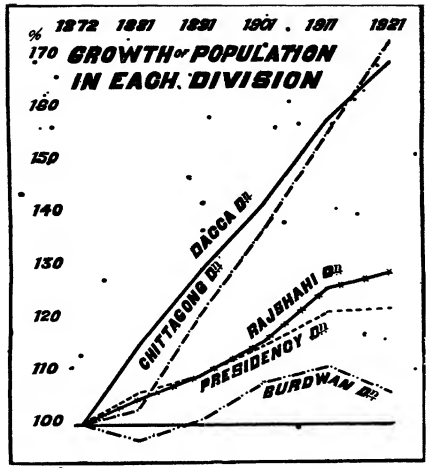
## Malaria and Agriculture in Bengal.

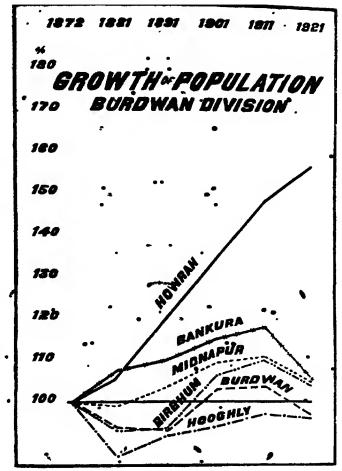
### 2—Public Health in Bengal.

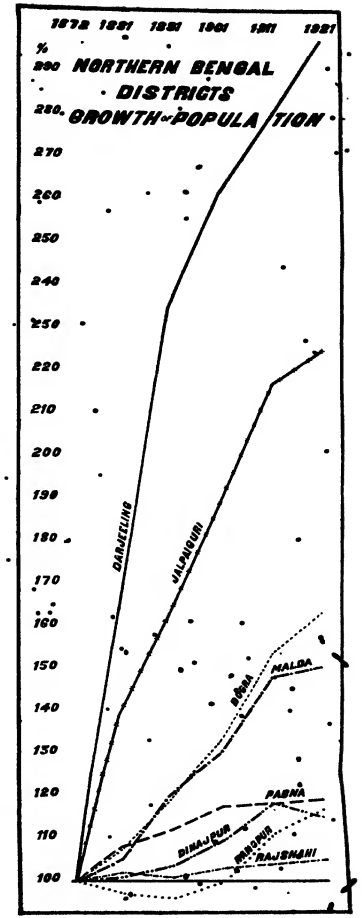
6. In Bengal, where the bulk of the people are dependent upon agriculture, low death-rates and good health accompany agricultural prosperity and high mortality and bad health on the contrary are as clearly associated with evidence of agricultural deterioration. This may be seen by comparing statistics regarding the health of the respective populations in the four great natural divisions of the province with certain figures reflecting the agricultural conditions prevailing in the same areas. In the decade 1901-11, the mean annual birth and death rates in each of the four natural divisions, viz., Western Bengal, Central Bengal, Northern Bengal and Eastern Bengal, were as follows :—

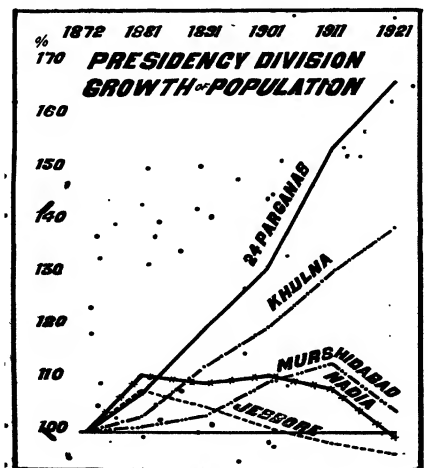
| Natural divisions | Mean recorded birth rates per 1,000, 1901 to 1911. | Mean recorded death rates per 1,000, 1901 to 1911 | Mean annual death rates corrected for migration per 1,000. |
|---|---|---|---|
| Western Bengal ... | 33·0 | 31·9 | 31·8 |
| Central „ ... | 33·8 | 33·2 | 30·5 |
| Northern „ ... | 38·8 | 34·8 | 32·0 |
| Eastern „ ... | 37·5 | 28·1 | 28·3 |

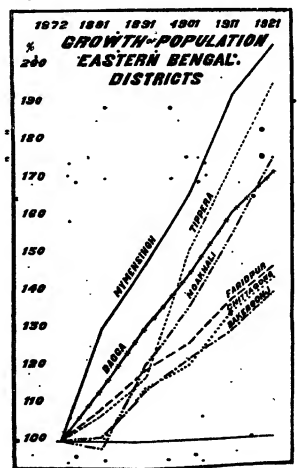
7. In the first three of the divisions, the death-rate during the decade was considerably in excess (13 to 23 *per cent.*) of that in Eastern Bengal, whereas the birth-rate in Eastern Bengal was much higher than in either Western or Central Bengal. As a direct result, the rate of natural increase of the population in Eastern Bengal was very much higher than elsewhere and nearly eight times greater than that of the Burdwan Division (Western Bengal). The total expansion of population in Eastern Bengal during the decade was over 12 *per cent.*, a figure far in excess of that in any of the remaining three


GROWTH OF POPULATION
IN EACH DIVISION
1872 1881 1891 1901 1911 1921
%
170
160
150
140
130
120
110
100
DACCA DIV.
CHITTAGONG DIV.
RAJSHAHI DIV.
PRESIDENCY DIV.
BURDWAN DIV.


GROWTH OF POPULATION
BURDWAN DIVISION
1872 1881 1891 1901 1911 1921
%
180
170
160
150
140
130
120
110
100
HOWRAH
BANKURA
MIDNAPUR
BURDWAN
BIRBHUM
HOOGHLY


NORTHERN BENGAL
DISTRICTS
GROWTH OF POPULATION
1872 1881 1891 1901 1911 1921
%
290
280
270
260
250
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
DARJEELING
JALPAIGURI
MALDA
RANGPUR
PABNA
DINAJPUR
BOGRA
RAJSHAHI

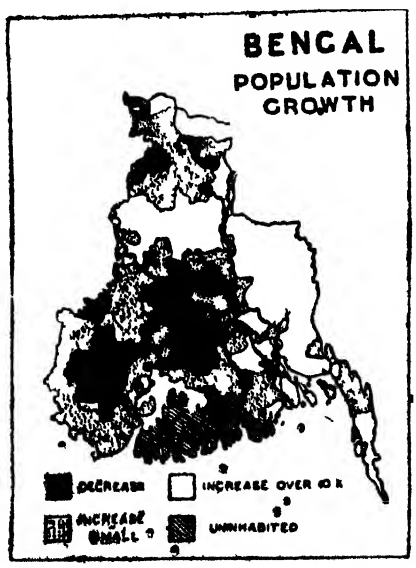

PRESIDENCY DIVISION
GROWTH OF POPULATION
1872 1881 1891 1901 1911 1921
%
170
160
150
140
130
120
110
100
24PARGANAS
KHULNA
MURSHIDABAD
NADIA
JESSORE


GROWTH OF POPULATION
EASTERN BENGAL
DISTRICTS
1872 1881 1891 1901 1911 1921
%
200
190
180
170
160
150
140
130
120
110
100
MYMENSINGH
TIPPERA
NOAKHALI
FARIDPUR
BACKERGANJ
BAKERGANJ
BOGRA

natural divisions, as may be seen from the figures given below:—

| Natural divisions | Excess of births over deaths per 1,000. | Mean annual rate of natural increase corrected for migration per 1,000. | Increase of population |
|---|---|---|---|
| Western Bengal ... | 1·1 | 1·2 | 2·8 per cent |
| Central „ ... | 0·6 | 3·2 | 5·1 „ |
| Northern „ ... | 4·0 | 6·7 | 8·0 „ |
| Eastern „ ... | 9·3 | 9·2 | 12·0 „ |

8. For many years past, the growth of population in Western and Central Bengal has undergone a serious check owing to diminished birth-rates and excessive mortality. The factors mainly responsible for this condition are malaria and economic stress resulting from agricultural decline. These factors are known to be specially destructive of child life, and the proportion of children under ten in the different natural divisions reflects their influence very clearly in the case of both Western and Central Bengal. In the districts of Western Bengal, the percentage of children in the population varies from 23·9 per cent. to 27·2 per cent., in Central Bengal from 27·1 per cent. to 30·3 per cent., in Northern Bengal from 26·6 per cent. to 35·0 per cent., and in Eastern Bengal from 29·1 per cent. to 34·7 per cent.



9. The following table gives the mean of the figures for the various districts of each natural division in 1911 together with the mean increase in young children during the previous decade and the mean proportion of children under 10 to married women, aged 15-40 years :—

| Natural divisions. | Children under 10 in population of 1919. | Increase of children under 10 since 1901. | Children under 10 to married women, aged 15-40. |
|---|---|---|---|
| | Per cent. | Per cent. | |
| Western Bengal ... | 25·5 | + 2·1 | 1·5 |
| Central „ ... | 28·0 | + 4·5 | 1·7 |
| Northern „ ... | 31·3 | + 11·4 | 1·9 |
| Eastern „ .. | 32·0 | + 13·1 | 1·9 |

10. The lower death-rate, higher birth-rate and more rapid growth of population in Eastern Bengal are due to the relatively better health and greater agricultural prosperity of this natural division. This has received recognition in the report of the Census of India for 1911 in the following passage :—

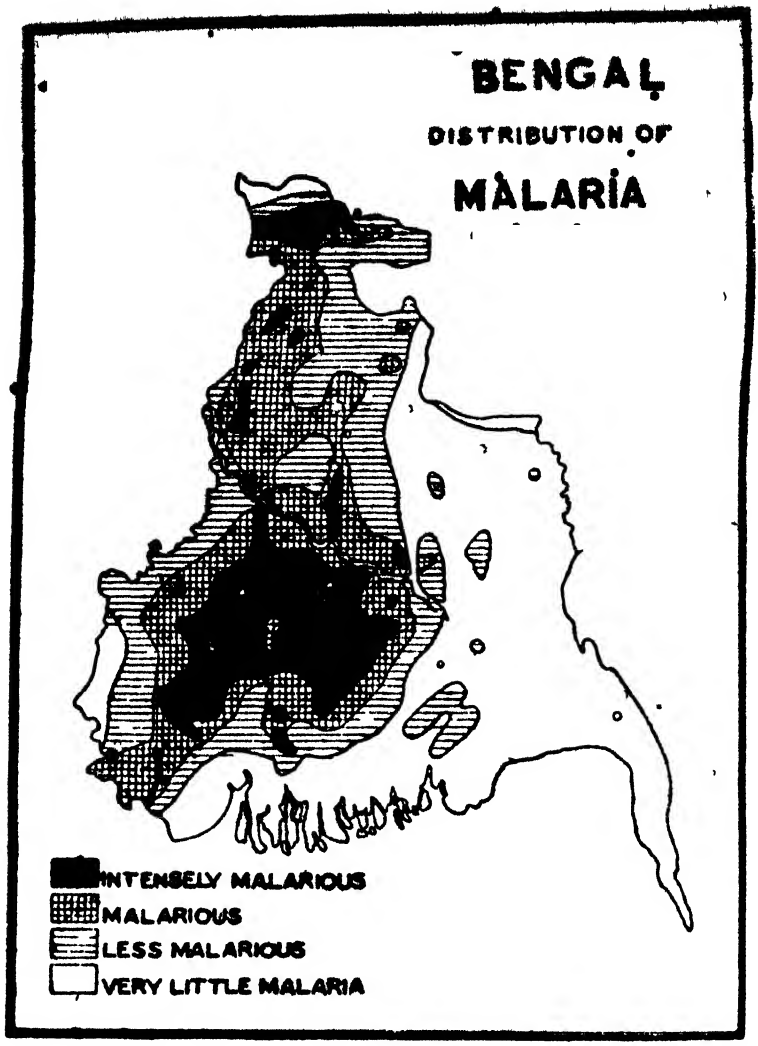
"Of the four natural divisions, the largest increase has occurred in East Bengal, where it is due entirely to natural growth. This tract is perhaps the healthiest in the province. It lies mainly in the joint delta of the Ganges and Brahmaputra rivers, where the fertility of the soil is replenished yearly by fresh deposits of silt."

### 3—Malaria in Bengal.

11. The lessened incidence of malaria in Eastern Bengal is the main cause of its better health. Malarial fever is at least three times more prevalent in Northern Bengal, four times more prevalent in Central Bengal and five times more prevalent in Western Bengal than in Eastern Bengal. The fever indices of the four natural divisions are given below :—

**Proportion of malaria cases total cases treated.**

| | Per cent. |
|---|---|
| Western Bengal ... ... ... | 40·9 |
| Central „ ... ... ... | 32·3 |
| Northern „ ... ... ... | 23·7 |
| Eastern „ ... ... ... | 7·5 |

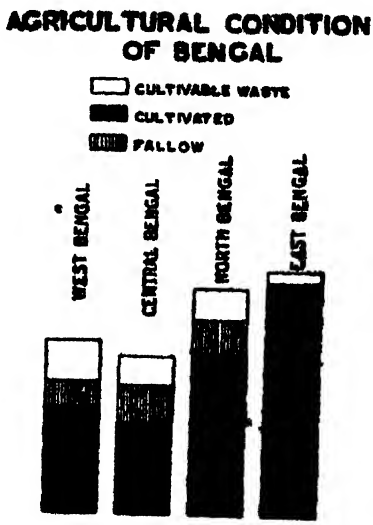



**4.—Agricultural Prosperity in Bengal.**

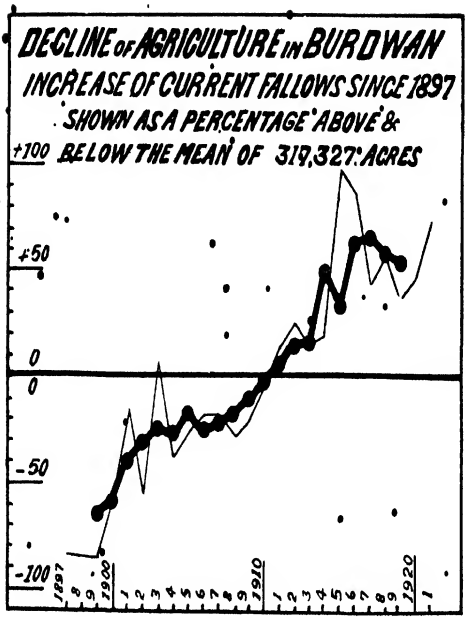
12. As regards agricultural prosperity, we find that during the decade 1901-11, agricultural conditions generally were much more favourable in Eastern Bengal than elsewhere. For example, whereas the outturn of the principal food crops fell short of the normal by 21·8 *per cent.* in Western Bengal, 21 *per cent.* in Central Bengal and 12 *per cent.* in Northern Bengal, the deficiency in Eastern Bengal was only 7·2 *per cent.* Land was also more widely cultivated in Eastern Bengal and the proportion

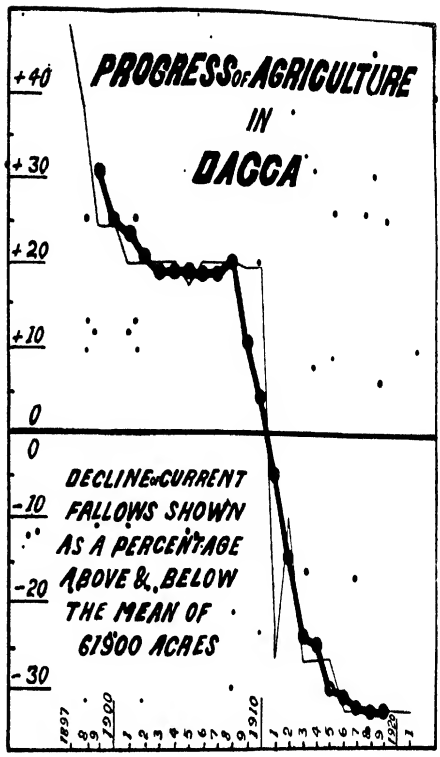
of fallows very much less than elsewhere, as may be seen from the figures quoted below :—

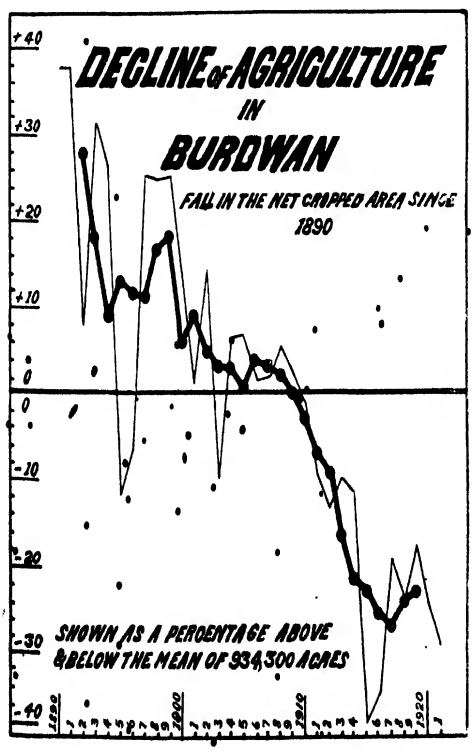
| Natural divisions. | Percentage by which the outturn of principal food crops fell short of the normal during decade, 1901-11. | Average deficiency in total crop outturn during 1901—1905 | Proportion of current fallow and cultivable waste to net cropped area. |
|---|---|---|---|
| | Per cent. | Per cent. | Per cent. |
| Western Bengal ... | 21·8 | 19·4 | 59·4 |
| Central „ ... | 21·0 | 20·4 | 52·6 |
| Northern „ ... | 12·0 | 8·9 | 31·4 |
| Eastern „ ... | 7·2 | 6·9 | 11·6 |

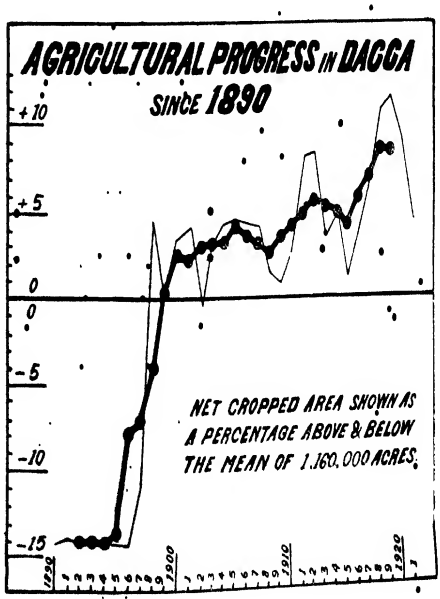



13. The factors which mainly determine the outturn of crops, thus governing the agricultural prosperity of different areas in Bengal are : (1) the relative fertility of the soil; (2) adequate and seasonal rainfall and (3) liability to enriching inundations with silt-bearing river water. Two of these factors, rainfall and inundations—also exert an important influence upon malaria, heavy rainfall and widespread inundation of the land surface tending to check the breeding of anopheles mosquitoes, whereas short rainfall and scanty inundations favour their increase. Hence the relative prevalence of malaria is largely influenced by the same conditions which determine either a good or a bad harvest.


DECLINE OF AGRICULTURE IN BURDWAN
INCREASE OF CURRENT FALLOWS SINCE 1897
SHOWN AS A PERCENTAGE ABOVE &
BELOW THE MEAN OF 319,327 ACRES
+100
+50
0
0
-50
-100
1897
1900
1910
1920


PROGRESS OF AGRICULTURE
IN
DACCA
+40
+30
+20
+10
0
0
-10
-20
-30
DECLINE OF CURRENT
FALLOWS SHOWN
AS A PERCENTAGE
ABOVE & BELOW
THE MEAN OF
61900 ACRES
1897
1900
1910
1920


DECLINE OF AGRICULTURE
IN
BURDWAN
FALL IN THE NET CROPPED AREA SINCE
1890
+40
+30
+20
+10
0
0
-10
-20
-30
-40
SHOWN AS A PERCENTAGE ABOVE
& BELOW THE MEAN OF 934,300 ACRES
1890
1900
1910
1920

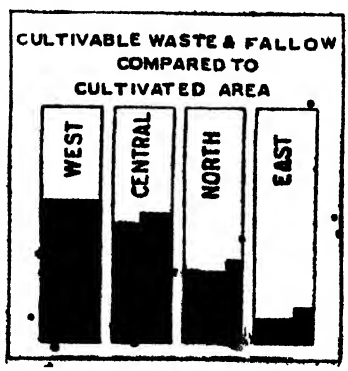

AGRICULTURAL PROGRESS IN DACCA
SINCE 1890
+10
+5
0
0
-5
-10
-15
NET CROPPED AREA SHOWN AS
A PERCENTAGE ABOVE & BELOW
THE MEAN OF 1,160,000 ACRES.
1890
1900
1910
1920

14. The soil in Eastern Bengal is so much more fertile than that in the other natural divisions that land rarely needs to lie fallow. The Director of Agriculture stated in 1908 :—

"Of fallow land in the European sense, there is practically none in Eastern Bengal, for cultivated fields are never intentionally given a rest. When a field is not cropped, it is simply because, owing to flood, drought or personal reasons, the *raiyat* is unable to cultivate it. The percentage of 'cultivated' land which in any year bears no crop at all is always very small. . . . In a 'normal' year it may, I think, be safely said that the area of current fallow in Eastern Bengal does not exceed one *per cent.* of the cultivated area."

15. A comparison of the proportions of current fallow and cultivable waste in four typical districts of Eastern Bengal in 1911 with the corresponding figures for certain districts in Central and Western Bengal serves to give some idea of the relative fertility of these different areas. The figures quoted below show how much more favourably placed in respect of fertility the districts of Eastern Bengal are than those belonging to the other natural divisions :—

| Districts in Eastern Bengal | Percentage of current fallow to net cropped area. | Percentage of culturable waste to net cropped area | Districts in Western and Central Bengal | Percentage of current fallow to net cropped area | Percentage of culturable waste to net cropped area |
|---|---|---|---|---|---|
| Faridpur ... | 4·0 | 9·5 | Murshidabad ... | 64·6 | 46·0 |
| Dacca ... | 3·9 | 2·7 | Nadia ... | 54·6 | 40·4 |
| Mymensingh ... | 2·5 | 11·5 | Burdwan ... | 45·0 | 24·5 |
| Bakarganj ... | 1·6 | 11·6 | Hooghly ... | 34·9 | 17·5 |



### 6—The Fertility of Eastern Bengal.

16. The causes both of the perennial fruitfulness of Eastern Bengal and the relative infertility of the western portion of the delta are well known. We read in the Statistical Account of Bengal that, "lands adjacent to rivers, or watered by them, do not require manure, but other lands do," "that low lands which are annually flooded do not require to lie fallow in order to preserve their fertility", and that in Eastern Bengal, "rotation of crops is nowhere practised, nor can it be said to be required, as by far the greater part of the arable land is each year refreshed with a new deposit of river mud." Both the *Imperial Gazetteer of India* and the various census reports point out that Eastern Bengal enjoys advantages for which it would be difficult to find a parallel in any other part of India.

"The rainfall is abundant, is usually well distributed and is never known to fail. *The land of the delta is enriched by yearly deposits of silt.* The climate, the soil and the river system are all alike favourable to cultivation."

"In its course through Bengal, the Ganges rolls majestically down to the sea in a bountiful stream.....Embankments are seldom required to restrain its inundations, for the *alluvial deposits, which it spills over its bank year by year, affords the fields a top-dressing of inexhaustible fertility.* The natural overflow of the periodic inundation is sufficient to supply a soil which receives in addition a heavy rainfall, and this natural overflow is allowed to find its own lines of drainage. *The plains of Eastern Bengal, watered by the Brahmaputra, yield abundant crops of rice, jute and mustard, year after year, without undergoing any visible exhaustion.*"

"The gneissic, laterite, and old alluvial soils are alike mainly dependent upon artificial manures to maintain their fertility, whereas the recent alluvium is periodically fertilised by fresh deposits of silt from the overflowing rivers. The latter process is most active in Eastern Bengal, in the deltas of the Ganges and the Brahmaputra, whose waters possess the fertilising properties of the Nile."

*Note*—The italics are mine—C. A B

### 7—The Impoverishment of Western and Central Bengal.

17. While the astonishing fruitfulness of Eastern Bengal is thus ascribed to the periodic flooding of the country, the relative impoverishment of Central Bengal is admittedly due to the cessation of the similar fertilising inundations which that area used once to enjoy. The report of the Census of India for 1911 states :—

"In Central Bengal, excluding the 24-Parganas, the conditions *are less favourable. The Ganges, having strayed further east, has*

*ceased to enrich the soil with its fertilising silt.* The numerous distributaries down which it once found its way to the sea have degenerated into stagnant lagoons, and the health of the people has thus been seriously affected."

The Bengal Census report of 1901 also refers to the condition of Central Bengal in the following words :—

"Central Bengal, which is bounded on the west by the Bhagirathi, on the north by the Padma, and on the east by the Madhumati, was formerly the Ganges delta, but it has been gradually raised above flood level, and the great rivers which formerly flowed through it, depositing their fertilising silt, yielding an ample supply of wholesome drinking water and draining it, have shrunk to insignificance. Their mouths have been silted up and their beds are often higher than the surrounding country, which they are no longer able to drain. The country has become less healthy, *and is far less fertile than it was formerly.*"

*Note.*—The italics are mine—C. A. B.

### 8—Agricultural Conditions in the individual Districts of Eastern Bengal.

18. Further enquiry in regard to the agricultural conditions of certain districts, typical respectively of Eastern Bengal on the one hand and Central Bengal on the other, throws still more light on the facts that have just been stated. One hundred and thirty five years ago, the *diwani* of Dacca, which at that time included the present districts of Dacca, Mymensingh, Faridpur and Bakarganj, had more waste land and jungle than any part of the province. Sixteen years later, it was estimated that "one-fourth of the southern, one-eighth of the eastern three-eighths of the western and five-eighths of the northern divisions of the district were still uncultivated and unde jungle." At the time of the permanent settlement, only one quarter of Mymensingh district was under cultivation and in 1839 Dr. Taylor estimated that one-third of Dacca district was still uncultivated. The change that has occurred since those days is very great. The *Dacca District Gazetteer* remarks :—

"There can be little doubt that, at the time when the Hon'ble Company took over the *diwani*, there were still considerable areas of waste land lying idle in every quarter of the district, whereas at the present day there is hardly a square foot of land outside Bhowal which has not been pressed into the service of man.....A subdivision like Munshiganj, that has a rural population approaching 2,000 to the square mile, must be clearly cultivated up to the highest limit, and there can be little doubt that for many years there has been no cultivable waste land in the district outside Bhowal."

"The really essential factor which determines the value of any given field is not so much the soil, of which it is composed, but the depth of the water which stands on it in the rains. And it is height and duration of the flood, even more than the local rainfall, which decides whether the harvest in Dacca will be good or bad. *These floods serve a double purpose, for they not only supply the crop with the moisture it requires but they restore fertility to the soil by the rich deposits of silt which they bring down*"

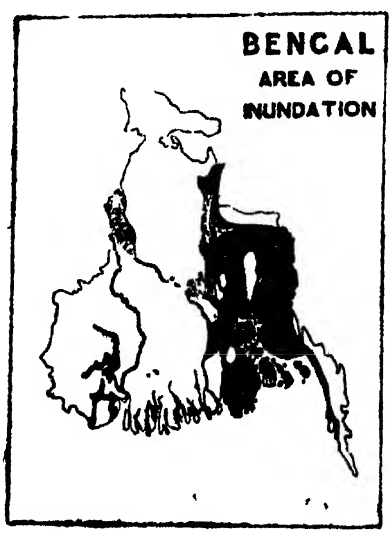
*Note*—The italics are mine—C. A. B.

"Hemmed in on three sides by the Jamuna, Padma and Meghna, Dacca is subject to all the vicissitudes of alluvion and diluvion, as well as to the periodic inundation and silt fertilisation characteristic of Eastern Bengal. These great rivers, as well as numerous smaller streams which intersect the district, annually flush and fertilise the land."

*Dacca District.*—"Much of the land in the district, too, has its fertility renewed by rich deposits of silt." (Dacca District Gazetteer.)

"The greater part of the district lies low and is flooded every year, but after the rains the flood water is drained off, and leaves the land enriched with a thick deposit of silt." (Census Report, 1901.)

"Dacca is at once the type and metropolis of Eastern Bengal; ..... it is subject to ..... periodic inundation and silt deposit which are characteristic of this fortunate part of the province." (Eastern Bengal and Assam Gazetteer.)




19. Every one of the alluvial districts of Eastern Bengal enjoys these advantages to a greater or lesser degree. And this fact has been brought into prominent notice in the various census reports and gazetteers from which the following extracts are taken :--

*Mymensingh District.*—"The north lies comparatively high and is generally above flood level, but the south is lower and is subject to

annual inundations and deposits of fertilising silt." (Eastern Bengal and Assam Gazetteer.)

*Tangail Subdivision.*—"Except in the east which contains part of the Madhupur Jungle, the subdivision is an alluvial tract, subject to annual inundations and deposits of fertilising silt." (Eastern Bengal and Assam Gazetteer.)

*Kishorganj Subdivision.*—"It is an alluvial tract, intersected by marshes, and is subject to annual inundations and deposits of fertilising silt." (Eastern Bengal and Assam Gazetteer.)

*Faridpur District.*—"The district is always inundated when the rivers rise in the rainy season, but the floods seldom cause more than temporary damage; and they are in fact beneficial, as they cover the country with a rich alluvial deposit." (Eastern Bengal and Assam Gazetteer.)

"The main crops are jute and a long-stemmed variety of winter rice which grows as the flood increases and will thrive in any depth of water provided that it does not rise too suddenly. Subject to this condition, the higher the waters rise the better: the silt deposited is proportionately increased, the sewage and other impurities which collect in the cold weather are more completely removed, and there is less difficulty in obtaining potable water during the winter months." (Census Report, 1901.)

"The annual inundations of the Padma and the Chandna supply sufficient deposits of fertilising silt, and little or no manure is necessary in the low-lying ground in which the *aman* crop is cultivated." (Statistical Account of Bengal.)

*Bakarganj District.*—"The district being, as already stated, one level, the water during the season spreads over the whole country and only the village sites, each raised on its own little mound, stand above the flood. These floods, however, leave behind them a thin layer of fertilising slime, which repays the peasant for the loss caused by the inundation."

"The district lies low, and except in the east, most of the country is inundated during the rains. The higher ground in the east produces sugarcane, pulses, the pan creeper and a little jute; the rest of the district is fertilised by rich deposits of silt and forms with Noakhali the most important rice-producing tract in Eastern Bengal." (Eastern Bengal and Assam Gazetteer.)

"The soil is extremely fertile, being annually enriched by the silt brought down by the rivers." (Census Report, 1911.)

*Tippera District.*—"Tippera is a level alluvial plain broken only by the isolated Lalmai hills....To the east, the country undulates and runs into the series of low forest-clad hills which form the most westerly of the hill Tippera ranges. The west is inundated during the rains." (Eastern Bengal and Assam Gazetteer.)

"Tippera enjoys exceptional advantages in regard to both climate and soil. The Meghna, which sweeps past the western border, enriches a large tract of land, on which fine jute is produced, while a number of smaller streams bringing down silt from the hills spread it over the greater portion of the district." (Census Report, 1911.)

*Noakhali District.*—"The soil is fertile throughout the district, the lands subject to the direct fluvial action of the Meghna being especially rich." (Census Report, 1911.)

"Little manuring is practised as the fertile soil, renovated annually by deposits of silt from the overflowing rivers, bears rich crops year after year without exhaustion."

*Chittagong District.*—"The hills streams are also heavily charged with organic matter from the decaying vegetation in the hills, and the silt which their waters deposit acts like manure and enables a rich succession of crops to be harvested." (Eastern Bengal and Assam Gazetteer.)

### 9—Agricultural Conditions in Northern Bengal.

20. A portion of Northern Bengal enjoys advantages similar to those which have brought prosperity to Eastern Bengal, as will be seen from the extracts quoted below. But in the centre and the west of the division, the land, is too high for inundations and in Rajshahi and part of Pabna they have also practically ceased.

*Malda District.*—"The low-lying recent alluvium in the west and south is enriched by annual deposits of silt, and its fertile soil is well adapted for the cultivation of rice, mulberry, indigo and mangoes."

It may be remarked, however, that of late years complaints have been made regarding the silting up of the rivers in Malda, and the author when touring in the district was told by a number of cultivators that fertilising inundations with river water were now less common than formerly.

*Rangpur District.*—"The Brahmaputra practically forms the eastern boundary for a distance of eighty miles....Its mighty stream exercises a great influence over the district by the fertilising effect of its inundation....The soil is remarkably fertile, being generally a sandy loam deposited by the rivers when in flood....The light alluvial soils are admirably suited to jute cultivation, and Rangpur yields an eighth of the whole output of Bengal, being second only to Mymensingh."

*Bogra District.*—"The east of the district, especially the densely populated Dhunot thana is low, and receives annual deposits of silt from the floods which cover it; the soil is friable and grows excellent crops of jute. Very similar conditions prevail in Sibganj and Shariakandi."

*Pabna District.*—'The Sirajganj Subdivision is low-lying, but, except in the Raiganj thana to the north, the drainage is not impeded by the high banks of dead rivers. It thus receives the benefit of an annual deposit of silt from the Jamuna. Unlike the rest of the district it is healthy, and the population is rapidly increasing."

21. From the passages quoted above, it may be seen that Eastern Bengal and certain parts of Northern Bengal owe their agricultural preeminence to the fact that they are each year inundated by the spill waters of the great rivers, which, besides affording an ample supply of moisture

for the purposes of cultivation, bring with them a rich supply of silt which is deposited upon the surface of the country, thereby renewing its fertility. And as we shall see later, it is the same agency which keeps these same areas almost free of malaria.

### 10—Agricultural Conditions in the Districts of Central Bengal.

22. Agricultural conditions in the western portions of the Gangetic delta make a very poor showing, compared with those in the east. Take the cases of Nadia, Murshidabad and Jessore: as far back as 1881, the report of the Nadia Fever Commission remarks:—

"*Diminished fertility of the soil in Nadia.*—There is a consensus of opinion among Europeans and Natives that, except in the lower lands used for the rice crop reaped in the cold weather, there is a distinct decrease in fertility of the soil of Nadia. Considering that no land except that used for sugarcane and tobacco is ever manured, and that the Ganges floods, which are so fertilising, are shut out by the embankments of the rivers, it is not to be wondered at that gradually the soil should become partially exhausted."

Even earlier than this time, the effect of diminished inundations had become apparent, as may be seen from the passages quoted below, which occur in two of a series of letters from indigo-planters, published in the Supplement to the *Calcutta Gazette* of 1864 in quite another connection.

Mr. J. P. Wise writes as follows:—

"In the low rich land affected by the inundation the *raiyats* go on year after year sowing their crops without experiencing any great deterioration. On the high lands depending on the elevation of the soil, and where not enriched by annual deposits, the *raiyat* merely extracts what he can without returning anything to it in the way of manure, and consequently this soil becomes exhausted, forcing them to let the land remain fallow for one or more years."

And Mr. W. B. Baldwin remarks:—

"In the Soobunkally Concern, I held lands that have been annually sown with indigo for 30 years, the last ten of which they had got beyond the influence of the yearly inundation, and therefore, the return was unprofitable. Upon which I gave up the lands to the zamindar....."

23. These two letters corroborate a statement in the *Nadia District Gazetteer*, regarding indigo cultivation in former days, to the effect that:—

"As the country was then lower than during later years, and more liable to fertilising inundations, the plant grew more luxuriantly and the crop was less liable to failure from drought."

Numerous other references have been made at various times to the growing infertility of Nadia. Certain passages from the *Nadia Gazetteer* read as follows :—

"The cultivators till the land for two or three years and then allow it to lie fallow for a year or two, the fertility of the soil not being sufficient to allow of uninterrupted cultivation" . . . . . "There seems little doubt that the main reason why the percentage of the population engaged upon agriculture is so comparatively low in Nadia is that the land is on account of its infertility, incapable of affording a livelihood to a large percentage."

"The Nadia district is a part of the old delta, but its rivers have gradually dried up and *it no longer receives the annual deposits of silt which formerly renewed its fertility.*" (Bengal Census Report, 1901.)

"The Ranaghat subdivision and a great part of the Sadar subdivision, on the other hand, barely support half this population. The low density is here due partly to *the silting up of the rivers which has deprived* the country of the silt it used to receive....." (Bengal Census Report, 1901.)

"In earlier days before the rivers had completed their work of land making, the district was far more liable than now to considerable inundations, which although they might destroy the crop which was actually standing at the time of their visitations brought with them a coating of silt, which ensured an excellent outturn for the following crop. *This enrichment of the soil, however, no longer takes place as frequently as it used to*, and as the very light manuring which is applied is insufficient to compensate for the loss occasioned to the soil by cropping, there can be little doubt that *the land is getting less and less capable of giving a good return* This is particularly noticeable in the steady diminution which has been taking place of late in the net area cropped in the district, which means that it is becoming increasingly necessary to allow the land to be fallow for longer periods During the last five years for which statistics are available, the average area of cultivable waste other than fallow was about 348,000 acres ; of current fallow about 400,000 acres and of net cropped land about 520,000 ; in other words, the net cropped area was only 41 per cent. of the total culturable area."

*Note* —The italics are mine—C A. B.

24. *Infertility of Nadia.*—The Director of Agriculture reports in *1910-11* and *1912-13* :—

"In Nadia, the soil is deteriorating on account of the gradual silting up of the river channels." "In the Kushtia subdivision of the Nadia district, the land is said to be losing its fertility by water-logging due to high embankments and insufficiency of culverts . . ."

Finally, the Census Report of 1911 contains the following quotation from a report of the Collector of Nadia on the same subject :—

"There is no doubt that the soil is getting less and less fertile. The average yield of crops is low as will be seen from the fact that the average yield of winter rice is 805 lbs. per acre and of autumn rice

835 lbs, while in Jessore it is 1,145 and 870, and in 24-Parganas it is 843 and 1,014, respectively. Another noticeable feature is that it is becoming necessary to allow the land to lie fallow for longer periods between croppings. During the five years from 1901-05 to 1908-09, only about 40 per cent. of the total cultivable area was actually cropped."

25. *Agricultural deterioration in Murshidabad.*—Agricultural deterioration has also occurred in the Murshidabad district and has been associated with a coincident decline in the public health. In 1809, Lord Valentia remarked of the Murshidabad district that :—

"The annual overflow of the river leaves a deposit of mud, which, like that of the Nile, gives richness to this otherwise barren country."

At the beginning of the last century, Cossimbazar Island, as the portion of Murshidabad lying between the Ganges, the Bhagirathi and the Jalanghi rivers was then called, was both exceedingly well-cultivated and very populous. Lieutenant John Pester stated in 1805 that Cossimbazar Island was then in a state of fertility equal to any garden *The Imperial Gazetteer* records that :—

"The decay of Cossimbazar dates from the beginning of the nineteenth century when its climate, which had previously been celebrated for its salubrity, underwent an unexplained change for the worse, so that the margin of cultivation receded and wild beasts increased."

In 1838, Montgomery Martin mentions that the climate of the Murshidabad district had deteriorated 17 or 18 years previously. "The unexplained change for the worse," detrimental alike to agriculture and population, appears to have been directly associated with the cessation of the periodical inundations, which used formerly to enrich the soil; and the decline of agricultural prosperity which followed was also accompanied by an increase of malaria. The cessation of inundations was directly due to the embanking of the rivers. Hamilton writing of the area speaks of "stupendous dikes not altogether preventing inundation but checking its sudden excesses." And recent census reports and gazetteers refer to the embankments and their effect upon agriculture as follows :—

"The district of Murshidabad is bisected from north to south by the Bhagirathi.....East of this river, the soil is low-lying and alluvial and forms a part of the old delta. It is fertile but liable to be flooded by the spill of the Bhagirathi and other rivers to prevent which numerous embankments have at various times been erected. The most important is the line of embankments along the left bank of the Bhagirathi. The propriety of maintaining all these embankments has often been called in question. The land which would

otherwise be flooded *is thereby deprived of its supply of fertilising silt* and the river being confined to its bed deposits its silt there and thus gradually raises itself above the level of the surrounding country." (Bengal Census Report, 1901.)

*Note.*—The italics are mine—C. A. B.

26. *Agricultural deterioration in Jessore.*—One of the earliest references to agricultural conditions in Jessore is to be found in the report of the committee appointed to enquire into the establishment of Fever Hospitals in Calcutta in 1842, which mentions that Jessore was a district subject to inundation, and explains that it was therefore far more fertile than the 24-Parganas. In 1870, Westland, when describing a considerable portion of Jessore, says that :—

"For some months in the year, the whole region may be said to be under water. The tract is not only liable to inundation, but the inundation is calculated upon, and the crops do not prosper without it . . . . The surface seems to be a series of basins, into which the waters flow through the khals, which, leading from the river, penetrate the high marginal land."

Since 1870, matters have gone from bad to worse in Jessore, as may be seen from the passages quoted below :—

"We find, therefore, that, with the exception of the Kumar, the interior Jessore rivers, namely the Nabaganga, Chitra, Kabadak, Bhairab, Harihar and the Bhadra, have within the last century ceased to be true deltaic rivers. They no longer convey the waters of the great Ganges to the sea, and have degenerated into lines of drainages which carry the local surface water to the Bay of Bengal. Hence it arises that the land lying north and west of the imaginary line from Kessabpur to Muhammadpur is ceasing to be delta land; and as a matter of historical fact, the northern and western parts of the district were far more liable to inundations eighty years ago than they are now. The country between the Kumar and the Nabaganga at that time regularly lay under water for several months every year, whereas it is now only reached by unusual inundation." (Statistical Account of Bengal.)

"In the south and south-east of the district, the lands are low, the rivers tidal, and there are many *bils* or morasses. In the north and north-west, the land is higher, having been raised by the deposit of silt from the rivers which traverse it This process has now stopped owing to the rivers having silted up at their head, the result of which is that periodical inundations which used to occur when they were in flood, have ceased. In the Jhenida subdivision, there have been no floods for the last 15 years, and *the country is the poorer for it*; while in the Magura subdivision, the floods are now comparatively slight and *the land is not fertilised to the same extent as formerly.*" (Jessore District Gazatteer.)

*Note.*—The italics are mine—C. A. B.

*Jhenida Subdivision.*—"Inundations from the Kumar still occur but at rare intervals. The surface has been raised by the inundations of distributaries of the Ganges till it is now beyond the reach of ordinary floods, and consequently *it no longer receives the deposits of silt which formerly enriched it.*" (Jessore District Gazetteer.)

"The average density of population is greatest in the east, where the soil is most fertile and still receives occasional deposits of silt, and least in the Bangaon subdivision in the west. The low density in the latter tract is due partly to the silting up of the rivers which has deprived the country of the silt it used to receive and partly to long continued unhealthiness." (Jessore District Gazetteer,)

*Narail Subdivision.*—"The Subdivision borders on the Faridpur district. The process of land formation has not yet ceased, and it receives occasional deposits of silt. It is less unhealthy than other parts of Jessore and the soil is very fertile . . . It is the most thickly populated part of the district." (Jessore District Gazetteer.)

The Gazetteer of the Jessore district states .—

"It is reported that cultivation has suffered from the deterioration of the rivers, which year by year used to deposit a layer of silt on their banks and in the *bils* during flood time.....This natural form. of fertilisation has ceased . . . The area under *aman* rice is contracting owing to deficient floods."

The following remarks from the annual season and crop reports issued by the Director of Agriculture afford further evidence of agricultural decadence in Jessore :—

1908. "*Agricultural deterioration.*—Large tracts in Magura, Narail and in the sadar subdivision of Jessore are showing signs of permanent deterioration owing to want of facilities for the ingress and egress of rain and flood-water."

27. *The causes of agricultural deterioration in Central and Western Bengal.*—The last quoted extract above is extremely significant, summing up as it does in a few words the main causes of agricultural decline in the districts of Central Bengal. And the same remarks apply to many parts of Western Bengal and other portions of the province also. Briefly, it is the want of facilities for the ingress and egress of rain and flood water, which is responsible both for a great decline of agriculture and the deterioration of the public health that has accompanied it. The indiscriminate embanking of vast tracts in lower Bengal primarily for flood prevention and secondarily owing to the construction of the network of railways and roads that now covers the country has caused serious

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damage alike to agriculture and to the health of the people. In 1912, according to the Director of Agriculture,—

"the district officers of Nadia, Burdwan, Midnapur, Howrah, Krishnagar and Murshidabad report agricultural deterioration..... In Krishangar, the gradual silting up of the river channels and the insufficiency of railway culverts are put forward as causes of deterioration."

28. There is a considerable amount of evidence to support the view that railway construction has been largely responsible for the disastrous change that has come over many parts of the delta in the last seventy years. Before the advent of railways, there were few roads and although river embankments existed in certain districts they were rarely efficient in preventing inundation, because breaches were common and more often than not the embankments were deliberately cut to let river water into the *bils* and on to the fields. As there were few roads to impede the free passage of the floods across the surface of the country, the water flowed from field to field, choosing the natural lines of drainage, and eventually made its escape through the network of khals and channels that existed in every part of the delta. But this natural process of flood and flush was destroyed by the advent of railways, which required embankments for their tracks and a system of feeder roads to convey passengers and produce to their stations. For the periodic inundation of the country naturally tended on occasions to destroy the continuity of road and railway communications and it became necessary therefore to make the river embankments secure against breaching; and in consequence flood water was shut out from the country, the natural system of deltaic irrigation was interrupted, drainage was impeded and the network of channels which used formerly to be fed by the spill water from the great rivers became silted up and in many cases entirely destroyed, rendering boat traffic difficult and in many cases impossible. The embanking of the country and the shutting out of river water from the surface of the delta was further marked by the simultaneous occurrence of appalling epidemics of malaria, a serious decline of agriculture and the progressive depopulation of the affected areas.

## CHAPTER II.

### The Effect of Embankments in causing Malaria and Agricultural Decline.

#### 11—Deltas naturally free of Malaria.

29. Contrary to what is often assumed and even definitely stated in the older medical text-books, deltaic swamps and the so-called "bottom lands" adjacent to large rivers are as a rule comparatively healthy and naturally free from a serious amount of malaria.

The freedom from malaria enjoyed by the delta of the Nile was mentioned by Strabo over two thousand years ago. And the same author remarked of Ravenna, a city in the delta of the Po-Reno, that like Alexandria, though surrounded by swamps it was free of marsh fever. Ravenna remained healthy for a long period. Thus Vetruvio cited it as an example of a well-situated and healthy city; and Chigi quotes Marzia as praising its salubrious air while complaining of the incessant croaking of the frogs. Ultimately, however, partly as the result of natural causes and partly owing to artificial changes, Ravenna became very malarious and has remained so for many centuries. The big deltas of China are known to be comparatively non-malarious. The troops from India encamped on the muddy flats of the Peiho and Peithang rivers in 1860, enjoyed an extraordinary immunity from malaria, and even those regiments which had suffered severely in India were exempt. "Even the depressed oriental race of China" says Wilson, "seems never to have had a difficulty in mastering the great problems which the necessity for the subjugation of rivers forces on civilized man; the Chinese waters have been turned to the most profitable account; their deltas seem healthy and abound with life . . . Agriculture is said to be perfect." The singular immunity of certain deltas from serious malaria has been reported from many other parts of Asia. Thus, in 1909 Mazzolani recorded in the transactions of the Italian Society for the study of malaria that, in the delta of the Sankoi in Tongking malaria is relatively mild in spite of extensive rice swamps and numerous anopheles. The same observer states that rice-swamps in the delta of the Mekong in Cochin China show the presence of anopheles mosquitoes with little or no malaria among the population.

30. The Great Dismal Swamp in Florida has long been considered remarkable owing to the fact that malaria is rarely or never contracted there. And although some parts of the Mississipi delta are malarious, other portions of the swampy littoral are reported to be healthy. The deltas of the big rivers in South America have long been known to be relatively non-malarious. Humboldt, Bates and Galt all record the comparative freedom from malaria observable in the delta of the Amazon in contra-distinction to the river valleys some of which are appallingly unhealthy. At a much earlier period Sir Walter Raleigh described his experience of the delta swamps of the Orinooco in his account of the "Discovery of the large, rich and beautiful Empire of Guayana" in the following words :—

"Moreover, the country is so healthful, as of one hundred persons and more (which lay without shift, most sluggishly, and every day almost melted with heat in rowing and marching, and suddenly wet again with great showers, and did eat of all sorts of corrupt fruits, and made meals of fresh fish without seasoning, of tortugas, of lagartos, and of all sorts, good and bad, without either order or measure, and besides lodged in the open air every night), *we lost not any one*, nor had one ill-disposed to my knowledge, nor found any callenture, or other of those pestilent diseases which dwell in all hot regions, and so near the equinoctial line."

31. Malaria is absent from the Pampas of the River Plate and the delta of the Parana river. Mantagazza (1858-62), confirming the previous reports of Wilson and Brunel (1842), states of the banks of the Rio-de-la-Plata that "paludal fevers are nowhere known" and Dupont (1868) remarked of the area around the mouth of the river :—

"Intermittent fevers are entirely unknown along the littoral (of the La Plata) ; it is difficult to say to what cause their absence is to be attributed, but all physicians are agreed that they are absent. The country presents at any rate all the geological conditions suitable for the development of malarial fevers, undulations of the surface hardly perceptible, periodical inundations over vast tracts of land, marshes and lagoons of great extent along the banks of the rivers, great elevation of the temperature in summer."

Bouffier (1857), speaking of the adjoining deltas of the Parana river and the numerous marshy islands at its mouth. remarks :—

"The numerous islands of the Parana are covered with innumerable marshes, which fill and empty with the rising and falling of the river . . . As soon as the river falls, an immense extent of marshy ground becomes exposed. For all that, I have not observed a single

case of intermittent fever, and from the information that I have been able to gather, it appears that this affection is rare among the indigenous inhabitants."

32. The deltas of some of the large African rivers are as yet comparatively free of malaria. The following passage ascribed to Stanley refers to the delta of the Congo river :—

"At Boma, on the edge of the river, in the midst of marshy exhalations, Europeans enjoyed better health than at Vivi, built on a rock in a dry region and 340 feet above the river. Also at Kirishass, 10 feet above the river, Europeans enjoyed immunity from disease while at Leopoldville, 95 feet above the river, sickness prevailed. Equator Station, 5 feet above the river, on a muddy creek and alluvial soil, was more healthy than Magunga, 240 feet above the river and 1,100 feet above the sea on a hill."

Daniels records in his report to the Royal Society that he was unable to find anopheles mosquitoes in the swamps at the mouth of the Zambesi ; and he mentions of a town at the mouth of the river that "Chinde now has the reputation of being a healthy place of residence." As regards the delta of the Niger, it may be mentioned that Annett, Dutton and Elliott, the members of the Malaria Expedition to Nigeria, spoke of Brass, which is in the delta, as "a comparatively healthy district".

33. In Sumatra, the low-lying areas along the flat banks of the Palembong river enjoy a comparative immunity from malarial fever. And the recent investigations of Terburgh show that there is little malaria at Palembong, Sourabaya, Padang and Banda. In Borneo, at Sambas, few cases of fever are to be met with in the marshy plains. Among 2,385 children examined in this situation only 78 or 3·2 per cent. showed splenic enlargement, whereas in a neighbouring hill station 441 among 534 or 82·5 per cent. had enlarged spleens.

The delta of the Irrawadi in Burma is relatively free from malaria. Sir H. Thirkell White, when speaking of his early charge of a district in the delta in his book "A Civil Servant in Burma," remarks :—

"In those days, the local mosquito apparently was not of the kind which carries malaria. Or perhaps owing to the backward state of sanitary education, he had not yet learned his trade. Cholera and small-pox excepted, the delta was comparatively free from serious diseases. Though swampy and water-logged, it was not beset with malignant fevers."

This view is supported also by the local dispensary returns which show that during 1911 the cases of malaria

together with "pyrexia of uncertain origin" treated at eight dispensaries in the delta represented only 3 per cent. of the total admissions, whereas in eight dispensaries in Upper Burma the ratio was 15 per cent.

A similar immunity from malaria is reported from the Godavari and Kishna deltas in Madras. The dispensary returns from these two districts show that during 1918 among a total of 449,614 and 363,107 out-patients admitted for treatment in these two districts only 5·5 and 3·1 per cent., respectively, suffered from malaria. In 1855, Baird Smith, in his report on Irrigation in Southern India, remarked upon the freedom from malaria enjoyed by the delta tracts of the Cauvari and Colaroon rivers, which have been irrigated for hundreds of years by flow irrigation. This is borne out by the dispensary returns for 1918 which show only 11,237 cases of malaria among 589,726 patients admitted for treatment, giving an astonishingly low fever index of only 1·9 per cent. The delta of the Mahanadi river in Orissa, although not quite so free of malaria as the Madras deltas just mentioned, also enjoys when compared with Bengal a relative immunity from the disease. Lieutenant-Colonel Fry, in his first report on Malaria in Bengal, records the fact that: "In the immediate neighbourhood of Cuttack, on the banks of the river Mahanadi, the spleen rate is less than 2 per cent., on the banks of the Taldana Canal the villages have about the same spleen rate". The dispensary reports for 1919 show that malaria cases represented only 11 per cent of the total admissions for treatment, which compares favourably with 25 per cent., the figure for Bengal as a whole and 50 per cent., that of many of the more unhealthy areas.

### 12—Deltas may become Intensely Malarious.

34. Deltaic areas though naturally healthy, so long as they are not interfered with, are yet almost always potentially malarious. Besides the case of Ravenna, which has already been mentioned, numerous instances may be quoted of deltas that have become notorious on account of the prevalence of malaria. For example, speaking of the Tuscan Maremma, a malarious tract watered by the Cecina, Corma, Pecora, Bruna, Ombrone and Albegna rivers, Baird Smith remarks:—

"It is to the disorganisation of these rivers that the ruin of a tract, which nature has endowed with the richest of soils and the

mildest of climates . . . with plains affording abundant pasture and fit for any kind of cultivation, is chiefly to be attributed."

In a further passage of his report, the same observer refers to the early history of Lombardy in the following words:—

"The neglect of even those works which in happier times may have been constructed . . . threatened to leave the rich plains of Lombardy in a state scarcely superior to that of the Tuscan Maremma, or the Pontine marshes. The same cause which has effected the ruin of these latter tracts was in active operation throughout Lombardy during the dark ages; the numerous rivers were unregulated and uncontrolled; and some notices of the state of the country during the tenth century prove that the inevitable results had followed, in the formation of vast marshes, and the abandonment of extensive districts."

Many of the malarious tracts of Italy have long since been restored from the state of ruin into which they had once fallen. Baird Smith quotes Bruschetti as remarking that:—"tracts now richly cultivated were then stagnant marshes or arid wastes."

35. India, too, can show examples of once prosperous delta areas sinking into a state of decay through agricultural decline and epidemic malaria and then being restored once again to a condition of health and prosperity by the reorganisation of their river systems. The Tanjore and the Rajahmandry districts in Madras, which have both passed through these experiences within the last century are striking instances. Much of Lower Bengal, on the other hand, is suffering at the present moment from disastrous changes similar to those which once threatened the existence of the more favoured deltas just mentioned. In this case the disorganisation of the rivers has been largely brought about or at least greatly hastened by human interference.

"It is not only through the hand of God" says Lieutenant-Colonel F C. Hirst "that the Nadia rivers and the country surrounding them are in their present unsatisfactory condition. For many years, human agency, by design, or accident, has contributed to affect the life of these rivers as well as the general condition of contiguous areas." . . . . "As the time went on, the number of embankments increased" . . . . "These embankments are of three types: (*a*) zamindari or protective embankments, (*b*) railway embankments, (*c*) road embankments."

The two latter classes of embankments are specially important from the point of view of the present report, because it is mainly since the construction of railways and roads, which now cover the country in every direction with a network of embankments, that vast portions of Lower Bengal have become subject to recurring epidemics of malaria, serious depopulation and agricultural decline.

### 13—Bengal a Country of Deltas.

36. An examination of the map of Bengal and its river systems shows that a very large proportion of the province is deltaic. The total area of the province is now 84,092 square miles, or, deducting the States of Cooch Behar and Hill Tippera, 78,699 square miles. Of this area, more than 75 per cent. is delta. The joint deltas of the Ganges and Brahmaputra alone cover from 50,000 to 60,000 square miles, and there are many smaller streams which possess deltas of not inconsiderable size. Western Bengal contains the deltas of the Salai, the Kasai, the Dhalkisor, the Damudar, the Adjai and the Mor and part of the delta of the Ganges. Central Bengal is entirely Gangetic delta. Eastern Bengal, with the exception of a few insignificant hill tracts, is almost entirely deltaic. It contains much of the living delta of the Ganges, the greater part of the deltas of the Brahmaputra, Surma and Barak, as well as smaller deltas such as that of the Mafimuhari. Northern Bengal contains portions of the Gangetic and the Brahmaputra deltas, together with the delta of the Tista, the lower portions of which have been usurped by the two former rivers.

Owing to their extraordinary fertility, deltaic areas tend to become densely populated and are relatively healthy and very prosperous as long as they remain subject to normal inundations with the spill water from their rivers. But changes tend to occur from time to time in deltaic rivers and such changes are apt to be followed by consequences serious alike to the health and prosperity of the areas affected. Changes in delta channels are often due to natural causes, but there is reason to believe that many of those that have occurred in the delta channels of Lower Bengal during the past sixty years are of human origin, and have followed the embankment of the country for the purpose of "*improved communications*". In this connexion, too, it is significant that reports have come to hand quite recently of the serious extension of malaria in the

delta tracts of Cochin-China, owing, it is suggested, to the more rapid spread of infection that has followed upon the improvement of communications. But the improvement of communications almost invariably means the construction of railways and roads; which in deltaic areas entails the multiplication of embankments; and these embankments, unless specially designed to avoid such results, eventually lead to the disorganisation of the river systems; the dislocation of natural flush and drainage, and other disastrous consequences, as agricultural decline, depopulation and epidemic malaria, such as have occurred during the last sixty years in Lower Bengal.

### 14—Former Lack of Roads in Bengal.

37. Prior to 1850 there were no railways, and few roads in Bengal. In 1802, there were only 20 miles of road in Jessore. In 1810, there were only six carts in Jessore town and not one hundred in the whole district, and water transport was preferred to land carriage. Between 1845 and 1868, a number of roads were constructed in Jessore district. It is noticeable that the earliest epidemics of malaria reported in Bengal were in that district, the first being associated with the construction of a road in 1836. Shore's notes on Indian Affairs under date May 1833 states :—

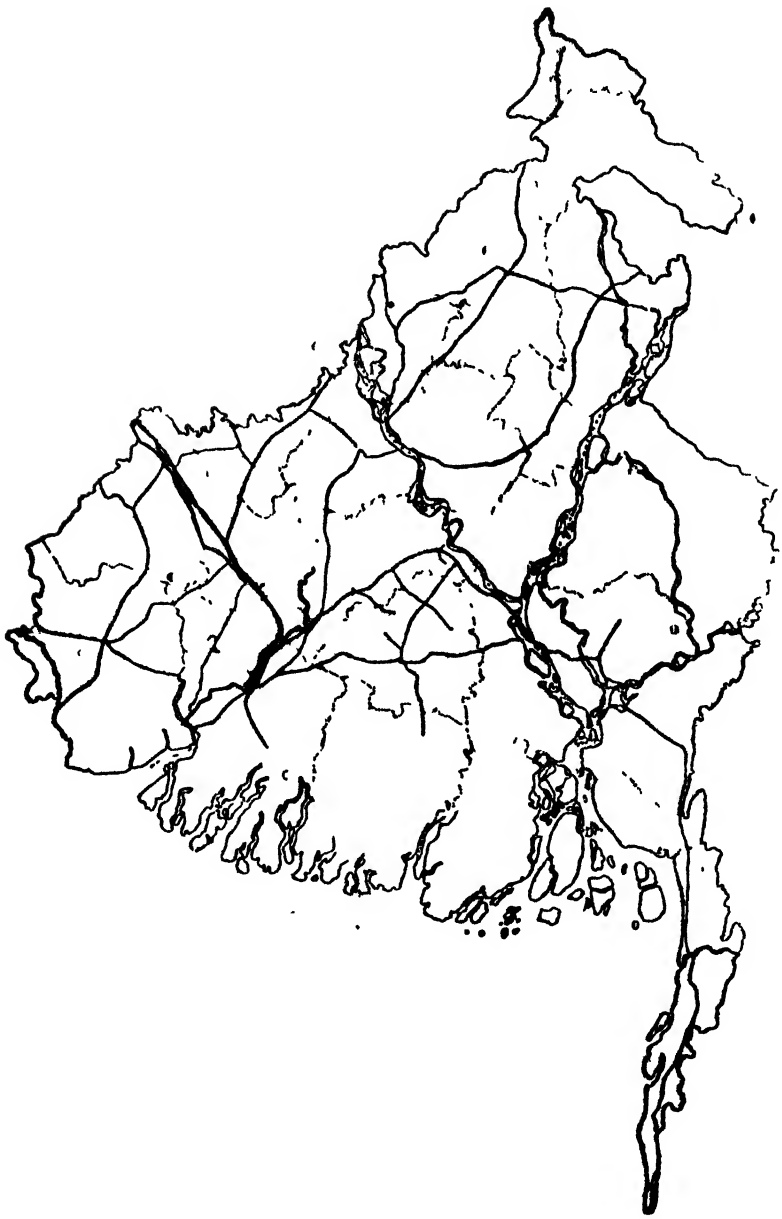
"As to roads, excepting those within the limits of civil stations, 16 miles between Calcutta and Barrackpur is all that we have to boast of."

In 1837, there was not a single road in Hooghly district which a European vehicle could traverse and in 1845 when bullock carts were required they had to be obtained from Calcutta. In 1838, Montgomery Martin commented on the absence of roads in Bengal and remarked that those laid down in Rennell's maps existed only on paper. In 1839, there were only two short roads in Dacca district, one to Narayanganj and the other to Tangi. Up to 1869, there were no roads in Pabna and in 1871 there were no roads and not a single cart in Malda.

### 15—Existing Roads and Railways.

38. The East Indian Railway was commenced in 1851 and the Eastern Bengal Railway a few years later. Work

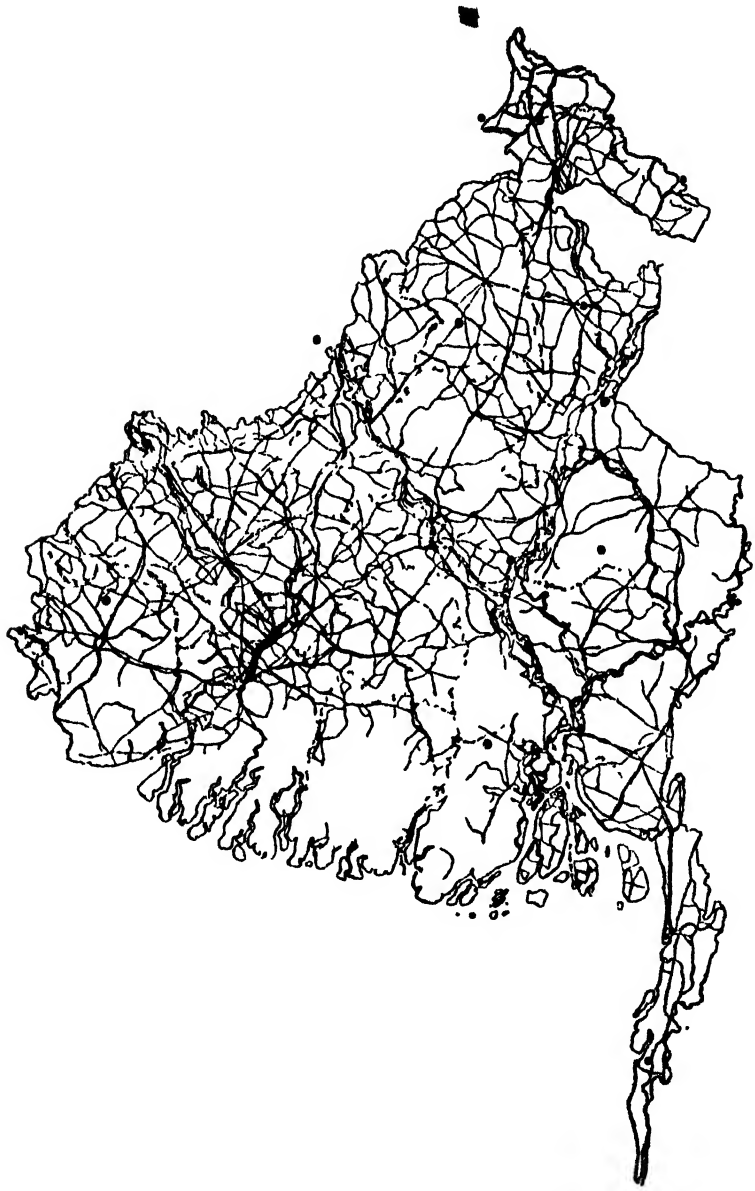
on the embankments of the latter were still in progres in 1863. Between 1872 and 1881, 525 miles of railway



Roads and railways in Bengal in 1870

were constructed in Bengal and Bihar and from 1881-91 a further 1,051 miles had been added to this total, still further increased by another 1,641 miles of open line by

the year 1901. At the present time, there are in Bengal over 3,000 miles of railway, more than 1,900 miles metalled roads and over 12,900 miles of unmetalled roa



Roads and railways in Bengal in 1920.

there are also over 14,000 miles of village roads, but these are mostly mere foot-paths or cart tracks. The mileage

and distribution of railways and metalled roads is shown in the following statement :—

**Roads and Railways in Bengal.**

| | Western Bengal. | Central Bengal | Northern Bengal. | Eastern Bengal | Total. |
|---|---|---|---|---|---|
| Area in square miles ... | 13,907 | (a)11,838 | (b)18,071 | 22,879 | 66,695 |
| Railways ... ... | 1,100 | 650 | 800 | 500 | 3,050 |
| Roads (metalled) ... | 1,170 | 502 | 129 | 120 | 1,921 |
| Roads (unmetalled) ... | 2,031 | 3,000 | 4,769 | 3,139 | 12,939 |
| Total ... | 4,301 | 4,152 | 5,698 | 3,759 | 17,910 |
| Miles of railways and roads per 1,000 square miles of area ... | 308 | 349 | 314 | 163 | 257 |

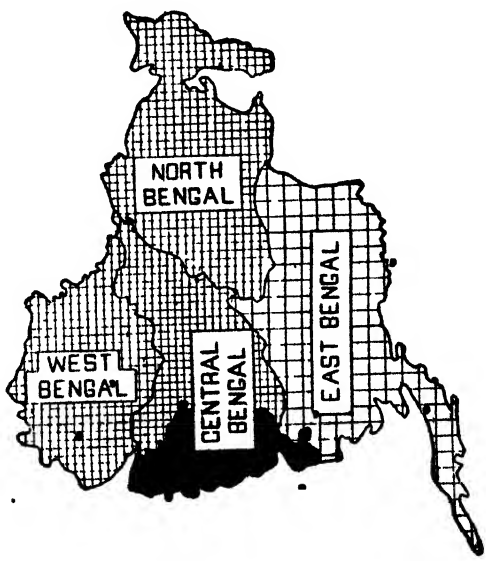
(a) Excluding large areas of forests in the Sundarbans.
(b) Excludes Darjeeling district.

39. It will be seen that Western Bengal is far better supplied with both railways and metalled roads than any other of the natural divisions. In proportion to its area, Central Bengal has a mileage of railway equalling 68 per cent. of that in Western Bengal. and Northern Bengal has 55 per cent.; whereas Eastern Bengal has only 26 per cent. Western Bengal is nearly twice as well supplied with metalled roads as Central Bengal, but Northern Bengal has a mileage in proportion only 8 per cent. of the former and Eastern Bengal has only 6 per cent. Central Bengal and Northern Bengal possess a greater mileage of unmetalled road than either of the two other divisions, and nearly twice as much in proportion as Eastern Bengal. The figures given below show the mileage of railways, metalled roads and unmetalled roads, respectively, per 1,000 square miles of each natural division, together with index numbers arranged for ease of comparison, Eastern Bengal being taken as the index :—

| Natural divisions. | Railways. | Index No. | Metalled roads. | Index No. | Unmetalled roads. | Index No | Total Index No. |
|---|---|---|---|---|---|---|---|
| Western Bengal ... | 79 | 376 | 83 | 1,660 | 146 | 106 | 308 : 187 |
| Central „ ... | 54 | 257 | 42 | 840 | 253 | 184 | 349 : 214 |
| Northern „ ... | 44 | 209 | 7 | 140 | 263 | 191 | 314 : 192 |
| Eastern „ ... | 21 | 100 | 5 | 100 | 137 | 100 | 163 : 100 |

40. The figures given above show that, taking railways and both classes of roads together, Eastern Bengal possesses little more than half the mileage in proportion to area possessed by the other natural divisions. Some conception of the way in which roads and railways have cut up the country may be got by the following illustrations:—(1) If the embankments of all the railways and roads in the four natural divisions were arranged in parallel lines across country so as to divide the country into narrow strips, the width of these strips would vary from a minimum of 2·88 miles in Central Bengal to a maximum of 6·08 miles in Eastern Bengal; (2) if the embankments were so arranged as to divide the whole country into squares, the size of these squares would vary from a minimum of 5·76 miles square, with an area of 33·17 square miles in Central Bengal, to a maximum of 12·16 miles square, possessing an area of 148 square miles in Eastern Bengal. The detailed figures are given below :—

| Natural divisions | Distance apart of embankments if arranged in parallel lines | Index No | Size of squares into which embankments would divide the country | Area of squares into which country might be divided by embankments | Index No |
|---|---|---|---|---|---|
| | Miles. | | | | |
| Western Bengal ... | 3·28 | 53 | 6·46 × 6·46 | 41·73 | 28 |
| Central ,, ... | 2·88 | 47 | 5·76 × 5·76 | 33·17 | 22 |
| Northern ,, ... | 3·17 | 52 | 6·34 × 6·34 | 40·19 | 27 |
| Eastern ,, ... | 6·08 | 100 | 12·16 × 12·16 | 147·86 | 100 |




Diagra indicating proportion of roads and railways in each natural division.

41. In low-lying deltaic country devoted to such crops such as rice and jute, the distribution over the fields of the water necessary for cultivation and the final draining of the land, which is essential for the aeration of the soil, are both greatly complicated by the existence of embankments which impede irrigation on the one hand and obstruct drainage on the other. And the evils that arise in consequence of the embankments tend to increase by geometrical progression in proportion as the amount of embanking increases.

### 16—Railways and Roads in relation to Cultivation.

42. On comparing the mileage of railways and roads with the total cultivable area and the area actually cultivated, certain interesting facts are brought to light, which suggest that in Bengal railways and roads do little or nothing to stimulate the bringing of land under cultivation. On the contrary, any direct influence which they exert on agriculture tends rather to its decline than to its improvement.

**Railways, Roads and Cultivation—Table I.**

| Natural divisions | Total cultivable area in acres | Mileage of railways and roads | Acres cultivable land per mile of road and railway | Percentage of cultivable area cultivated | Miles of railway and roads per 100,000 acres cultivable area. | Miles of rail and road per 100,000 acres net cropped area |
|---|---|---|---|---|---|---|
| Western Bengal | 7,044,293 | 4,301 | 1,642 | 61·5 | 61 | 99 |
| Central „ ... | 6,486,455 | 4,152 | 1,562 | 58 5 | 64 | 109 |
| Northern „ ... | 9,349,044 | 5,698 | 1,640 | 70 9 | 60 | 85 |
| Eastern „ ... | 10,213,710 | 3,759 | 2,716 | 89·0 | 36 | 41 |

The figures cited show that the proportion of land now under cultivation is greater in Eastern Bengal than elsewhere, although the mileage of roads and railways is relatively low in that natural division. But Eastern Bengal possesses 12,000 miles of navigable channels open throughout the year and expanding to 24,000 miles in the flood season. Central Bengal, the division best supplied both with road and railway communication, has only 58·5 *per cent.* of its cultivable area cultivated, compared to 89 *per cent.* in Eastern Bengal. But in the former division,

agriculture has admittedly been undergoing serious deterioration for a number of years past.

### 17—Roads, Railways and Waste Land.

43. An increase of railways and roads in deltaic tracts does not tend to bring land under cultivation, although it may possibly have this effect in more elevated areas. The following figures show the proportion of cultivable waste land in each natural division and its relation to road and railway communication :—

**Railways, Roads and Cultivation—Table II.**

| Natural divisions | Miles of railways and roads per 1,000 square miles | Cultivable waste land in acres | Percentage of cultivable area lying waste | Percentage of cultivable waste land to net cropped area | Cultivable waste land in acres per mile of railways and roads |
|---|---|---|---|---|---|
| Western Bengal ... | 308 | 1 783 063 | 25·3 | 41·1 | 414 |
| Central ... | 349 | 1,144,205 | 17 6 | 30 1 | 275 |
| Northern , ... | 314 | 1,316,615 | 14 0 | 19 7 | 231 |
| Eastern ,, ... | 163 | 751 263 | 7·3 | 8 2 | 199 |

It will be seen that, in spite of their better road and railway communications, the waste land available for cultivation in Western, Central and Northern Bengal far exceeds that existing in Eastern Bengal.

### 18—Roads, Railways and their Effect upon Fertility.

44. There are grounds for believing that the multiplication of roads and railways has been a cause in some areas of land actually going out of cultivation. The effect of embankments upon the fertility of cultivable land has to be considered in this connection, and a passage quoted below from the Bengal Census Report of 1911 has special bearing on this question .—

"There is no doubt that in areas liable to inundation the embankment does frequently alter the drainage of the country. On the one side, floods are deeper and last longer than before, and the soil becomes water-logged, *on the other, the land does not receive the same amount of moisture or the same fertilising deposit of silt.*"

*Note.*—The italics are mine—C. A B

45. In the deltaic portions of Bengal, cultivable land, ordinarily subject to inundation with river water, never requires to lie fallow whereas other lands do. Fallows therefore may be taken as an index of soil impoverishment Embankments prevent inundation by river water and from this point of view the following figures are of great interest and importance:—

**Railways, Roads and Fallow Lands.**

| Natural divisions. | Total acres fallow. | Fallow land in acres per mile of railway and road. | Proportion of fallows per 1,000 acres cropped. | Miles of railways and roads per 100,000 acres net cropped area. | Average percentage deficiency of crop outturn. |
|---|---|---|---|---|---|
| Western Bengal ... | 928,030 | 215 | 214 | 99 | 21·8 |
| Central ,, ... | 1,544,150 | 371 | 405 | 109 | 21·0 |
| Northern ,, ... | 1,372,629 | 240 | 206 | 85 | 12·0 |
| Eastern ,, ... | 371,747 | 98 | 40 | 41 | 7·2 |

46. In proportion to the cultivated area, fallow land is five times as common in both Western and Northern Bengal than in Eastern Bengal, and in Central Bengal the proportion of fallow land is just ten times as great as that in Eastern Bengal. In view of the facts stated, the multiplication of railways and roads in the deltaic portions of Bengal is to be regarded with grave misgivings. The embankments exert a most deleterious effect upon the fertility of the soil, thus causing a serious decline in the agricultural production of the areas they serve. Roads and railways afford, it is true, excellent facilities for the transport of goods and especially for the rapid transit of passengers. But these advantages may be too dearly purchased, if the construction of the necessary embankments brings about, as it may do, in course of time a fifty per cent reduction in the agricultural outturn of whole districts, turning healthy areas into hot-beds of malaria and eventually leading perhaps to the destruction of nearly half their total population.

### 19—Effect of Embankment on the Public Health.

47. In the early sixties, when outbreaks of epidemic fever first attracted serious attention in Bengal, the occurrence of the disease was ascribed to the construction

of embankments. The chief exponent of this theory was Raja Digambar Mitter, the Indian Member of the first committee appointed by Government in 1863 to enquire into the causes of the epidemic. Among the instances quoted by Raja Digambar Mitter in which fever had broken out shortly after the construction of extensive embankments, the case of the continuous line of villages from Ichapur to Chakdaha, numbering among them such thickly populated places as Halishahar and Kanchrapara, was mentioned. The people in these villages suffered from a severe type of fever, which broke out exactly in the order of time in which the railway embankment progressed and passed along their eastern borders. Another instance was the line of villages from Pandua to Kalna, in which fever broke out after the construction of two roads in their vicinity. A further case was that of an outbreak of fever in the villages of Khalatpur, Saota, Tanksabi, Gaura, Saibona, Langalpara, Raghunathpur, Kishannagar, Gopalnagar, Narainpur and Khanakul, which occurred shortly after the construction of a *kacha* road from Mayapur to Khanakul in the Hooghly district. From time to time, a great number of other outbreaks were attributed to similar causes. In a report on the epidemic fever submitted to Government by the Commissioner of the Presidency Division in 1874, the following passage occurs :—

"The other cause to which defective drainage may fairly be attributed is embankments. Babu Digambar Mitter has laid much stress on this, but it is still a moot point. Many professional engineers are of opinion that railways and roads have nothing, or next to nothing, to do with the fever. But I find something in this division to support the other view. Dr. Elliot names Muhammadpur as the first place where the epidemic broke out with virulence. Inquiry shows that *the great* outbreak there was in 1836, and not 1824 or 1825, though there may possibly have been two outbreaks. However this may be, it is stated that it broke out while the Jessore and Faridpur high road was being carried through the village. It seems possible that the very severe fever that prevailed in Belghurria, just north of Calcutta, nearly every year, may have owed its origin to railway embankment. It used in old days to be a very thriving place, but since then it has become desolate and uncared for . . . . . The south suburban town suffers every year from a devastating fever in the months of October, November, December and January, and the people attribute this to the escape of water being prevented by the Diamond Harbour Road."

48. In 1878, the Sanitary Commissioner, commenting upon the epidemic during the construction of the Jessore and Faridpur roads, recalled the fact that a similar outbreak occurred when the Grand Trunk Road (which runs from

Howrah to Lahore) was being made. The Sanitary Report of 1884 alludes to an epidemic of malaria which broke out when the railway was being constructed between Dacca and Mymensingh. And other outbreaks had previously been reported during the construction of the Northern Bengal and North-Western Bengal Railways. Fever became intensely prevalent from 1896 onwards in Nowgong during the construction of the Assam-Bengal Railway from Gauhati to Lumding. The Sanitary Report of 1907 also contains the following reference to an outbreak of fever in Murshidabad :—

"The Civil Surgeon is strongly of opinion that the newly constructed Murshidabad branch of the Eastern Bengal Railway has affected the public health. He says that the railway engineering authorities have been guilty, as elsewhere, of taking absolutely no means of draining the pits and hollows by the side of the embankment, and that he is convinced that in such a malarious neighbourhood, especially as that of Murshidabad town, this has led to increased unhealthiness and should be remedied."

49. In 1910, Major McCombie Young, I.M.S., called attention to an outbreak of malaria in the Malda district, which had occurred during the construction of the railway there. Lieutenant-Colonel Fry, I.M.S., in his second report on malaria in Bengal, mentions that an outbreak of malaria had recently occurred in the north-western portion of Murshidabad district, which coincided in point of time with the construction of a new railway line there. Similar untoward results have followed the embanking of the rivers for purposes of flood protection. For example, an outbreak of fever followed the embanking of the Nabaganga in 1858, and a similar outbreak was reported in Kristanagar thana of Hooghly district in 1873, as a result of the embanking of a *khal* in the vicinity. In 1893 also, the Magistrate of Murshidabad stated that the prevalence of fever in that district was largely attributable to the embankments protecting that part of the country "the unhealthiest areas being always those best protected by embankments." Subsequent investigation has shown that this view is founded upon fact, as may be seen from Stewart and Proctor's report on malaria in the Murshidabad district, in which they record that :—

"In the Bhagwangola and Lalgola thanas, 26 spleen rates were taken with an average of 32·7 ; of these, 13 villages were outside the retired line of the Bhagirathi embankment, unprotected from the annual flood of that river, and gave an average spleen rate of 29·9 and 13 villages were inside the embankment and not flooded annually from the river, these gave an average spleen rate of 35·6 per cent."

If the villages examined by them on the east bank of the Bhagirathi are divided into two classes, according to their situation within or without the embankment, the results are still more marked ; for the mean spleen index of 26 villages outside the embankment is 27·0 per cent., whereas 29 villages inside give a mean spleen index of 60 per cent.

50. Recent observations have shown on numerous occasions that, following the construction of embankments, there is a very great local extension of malaria on both sides of the embankment, accompanied by a rise in the local mortality, an increase in the proportion of fever cases and fever deaths and a rise in the spleen index. Changes of this kind have been noted and specially reported on in detail in the case of the railway from Katwa to Sahibganj, in Birbhum and Murshidabad, in the case of embankments connected with the Sara Bridge and in the case of the Sara-Sirajganj Railway. A considerable rise in the fever index has also been noted in the case of recent railway construction in Mymensingh.

51. The occurrence of outbreaks of malaria in association with the construction of embankments has never been disputed, and the observation in regard to the sudden increase of the spleen index in the neighbourhood of these embankments is conclusive. But the manner in which embankments bring about this admitted increase of malaria requires to be made clear, in order that adequate steps may be taken to remedy the condition and to prevent the further extension of the evil.

# CHAPTER III.

## Agricultural Decline in the Burdwan Fever Tracts.

### 20.—The Burdwan Fever Epidemic.

52. Enough has been stated to show that the embanking of the delta tracts of Bengal, whether for roads, for railways or for flood prevention, is almost invariably followed by the most disastrous consequences alike to health and to agriculture. This view is greatly strengthened by a consideration of the circumstances which led to the great Burdwan fever epidemic of sixty years ago. The special committee appointed in 1863 to investigate this epidemic fever, reported in 1864 that the area first affected by the disease had recently ceased to be inundated and enriched by flood water from the rivers.

"The tract of country, within which the fever has, during the last few years, appeared in an unusually violent form, extends from the station of Krishnagar on the north to Rajahath and the adjoining villages on the south; and from Dwarbashini, six miles from Pandua, on the west, to Srinagar, about twelve miles from Chogdah, on the east. Beyond this tract, the disease has appeared with extreme virulence in only a few isolated places, as Meherpur, Jayrampur and Gudkhali. The tract specified is traversed by the rivers Hooghly, Matabhanga and Jabuna, and by numerous khals, some of which communicate with the Hooghly and others with tidal rivers. In the greater number, probably all of these khals, throughout the whole or a portion of their extent, the flow of water is obstructed by obstacles natural and artificial . . . The surface of the infected track is, therefore, inundated for the most part by rain only, and but to a limited extent by the river water, and is consequently not enriched by an annually-deposited layer of fresh alluvial soil as the districts to the eastward are."

A little earlier, Dr. Elliot in a report on the "Epidemic Remittent and Intermittent Fever occurring in parts of Burdwan and Nadia Divisions", remarked that one of the principal causes of the epidemic was want of cultivation. He had almost invariably observed that the epidemic appeared first and was most virulent in the oldest and most populous villages, the lands in and around which had gone out of cultivation. Thus, while the Fever Committee showed that the fever was associated with relative infertility of the soil owing to lack of inundations, Dr. Elliot commented on the associated lack of cultivation. The one statement corroborates the other, for, as is well known, lack of fertility leads to lack of cultivation.

53. Raja Digambar Mitter first pointed out that embankments were the cause of the epidemic fever; and a little later his views were corroborated by a host of other observers. Thus in 1869, Dr. Thompson, Civil Surgeon of Hooghly, reporting on the epidemic fever in that district, remarked :—

"What then are the causes which ..... have caused a once flourishing district to be half populated, and which threaten to throw half the land out of cultivation? The portion of the Hooghly district which has suffered most from the ravages of this fever is that comprised between the Damudar and the Hooghly rivers. Intersecting this land from west to east run many *khals* or rivulets . . . They were the means where the floods of the Damudar found egress into the Hooghly. They were not only the safety valves to the Damudar, but they exercised a fertilising and sanitary influence on the whole surface of the district. But it was found (as often happens) that this process was not wholly beneficial. It had the inconvenience of inundating a large tract of country in seasons of great flood and thus crops suffered and the revenue also. A remedy was proposed and carried out; a *bund* was constructed on the left or eastern bank of the Damudar, cutting off the head waters of the khals; and these in consequence commenced silting up."

In the same year, Mr. Cockerell, the Magistrate of Hooghly, reported to the Commissioner that—

"As regards the possible effect which the stoppage of the Damudar waters may have had on the health of the district, it certainly appears to me a coincidence worth bearing in mind, that while one would naturally seek for some special cause to explain the sudden change in the health of the population of a whole district within a few years, the date from which these outbreaks of sickness in the present aggravated form commenced, is within a year or two of the final closing of the Damudar *khals*."

In a letter to Government also written in 1869, Mr. Buckland, the Commissioner of the Burdwan Division, after pointing out that only a small portion of Burdwan had hitherto been attacked by the fever, makes the significant remark: "The portion so attacked is manifestly that which used to be subject to inundation from the Damudar, before the embankment on the left side of the river was made proof against breaching."

### 22—The Effect of Embankment on Agriculture in Burdwan and Hooghly.

54. As to the disastrous effect of the shutting out of the Damudar water on the agriculture of Burdwan and

*Hooghly*, evidence recorded in the Burdwan Fever Report of 1873 is specially instructive, as the following extracts will show :—

"The profits of the agricultural classes in this district (*Hooghly*) are less now than in 1860 . . . The reduction of profits as now accounted for, firstly, by the decreasing fertility of the soil in those parts of the district which were within the sphere of influence of the Damudar inundations."

"Wherever I went there was one answer from the raiyat that the productive powers of the soil have diminished of late . . . The greater part of the district has been seriously affected by the bunding of the Kananadi and the embankment on the eastern bank of the Damudar; the silt of the Damudar can no longer enrich the soil in these parts."

"The fertility of the soil has within the last thirty years certainly diminished to some extent. The annual floods of the Damudar, which used to leave deposits of healthy silts on the lands all over the district and thereby enrich the soil, have ceased to come upon them since construction of the left bank embankment."

"Though the people (of Burdwan) have enjoyed safety from inundations of the river yet their lands have lost in fertility owing to the loss of alluvial deposits which the water used to leave before."

In the same year, Dr. Ray, M.D., F.R.C.S., an inspecting medical officer who visited the affected area, reported on the cessation of inundations as the result of the embankment as follows :—

"A powerful water-purifying agency has been cut off in a district, which must necessarily tell on the health of the population. Fish has grown scarce, whilst formerly six pice used to purchase one seer of fish; the same quantity cannot be had for less than four annas. Nor are these all. The productive power of the ground has much deteriorated and the water which used to flush the land and wash away the impurities has ceased to act. There is no longer any proper drainage, and no wonder that all these causes in operation will add their quota to aggravate the mischief."

### 23—Former Prosperity of Burdwan and Hooghly.

55. Prior to the shutting out of the Damudar floods, the condition of the affected area was one of almost unexampled prosperity. In 1760, Burdwan, which then covered an area of 5,174 square miles and included the present districts of Hooghly and Howrah, was described by the officers of the East India Company as the most productive district within the whole province or *subah* of Bengal. It was also spoken of as "a garden in the midst

of a wilderness." In 1815, the same area was referred to by Hamilton in the following words:—

"That this district continues in a progressive state of improvement is evident from the number of new villages erected, and the increasing number of brick buildings both for religious and domestic purposes, nor is there any other portion of territory in Hindusthan that can compare with it for productive agricultural value in proportion to its size. In this respect Burdwan may claim first rank, the second may be assigned to the province of Tanjore in the Southern Carnatic."

In another passage, the same authority states that no less than seven-eighths of the land in Burdwan was then under cultivation. Further corroboration of the former flourishing condition of this area is to be found in a Memoir on the Husbandry and Internal Commerce of Bengal, published by Colebrooke at the beginning of the last century, wherein it is shown that the land revenue then payable by Burdwan district (5,174 square miles) was at the rate of Rs. 842·2 per square mile, as compared with Rs. 476·4, the next highest rate in the province, paid by the 24-Parganas, Jessore and Murshidabad.

### 24—Loss of Population of Affected Areas.

56. Dr. Elliot estimated in 1872 that prior to the outbreak of the fever in Burdwan, the density of the population was not less than 750 persons to the square mile whereas in 1911 it was 572. The Census Report of 1881 states :—

"Having regard to the fertility and prosperous state of Burdwan and its well-known comparative salubrity prior to 1861, I should not hesitate to assign to it a higher population per house than the average; but assuming only the average rate of 5·7 persons per house, the population of the area included in the present district of Burdwan could not in 1861 have been less than 2½ millions."

Lt. Col. Crawford also states of Hooghly that—

"It would appear that, before the fever broke out, the Hooghly district must have had a population of something like 2,000,000 and that during the 20 years, the fever lasted, the population fell by about 50 per cent."

The decline of population in Burdwan and Hooghly, referred to by Dr. Elliot and Col. Crawford, still continues, not only in those areas but also in many other parts of Bengal that have been similarly affected, and the Census

of 1911 revealed the fact that during the previous decade depopulation had taken place in many *thanas* in different districts. The aggregate of the decadent *thana* areas in each natural division was as follows :—

| | Total area. | Decadent area. | Percentage of total area decadent. |
|---|---|---|---|
| Western Bengal ... ... | 13,907 | 5,339 | 38·3 |
| Central „ ... ... | 11,838* | 5,262 | 44·8 |
| Northern „ ... ... | 19,235 | 3,175 | 16·5 |
| Eastern „ ... ... | 22,879 | 1,358 | 5·9 |

* Excludes a large area of reserved forest in the Sundarbans.

The decline of population is most extensive in Western and Central Bengal, where there are most embankments and where agriculture has suffered the greatest deterioration. In almost every case also the decline of population is associated with the extensive prevalence of malaria. It is significant that the decline is least pronounced in Eastern Bengal which is not so well provided with embanked roads and railways and where the country has not been protected from inundation by marginal river embankments. Where in a few areas depopulation is occurring in Eastern Bengal it is associated with the embanking of the country, a local decline in agriculture and a coincident increase of malaria.

### 25—The Economic Question.

57. Economists recognize that "if the population of a district is increasing at a rate above the average, this is *prima facie* evidence that its industries are prospering; if the population is decreasing or not increasing as fast as the average, this strongly suggests that the industries are suffering from a temporary lack of prosperity or permanent decay." The rural population of Bengal is wholly dependent upon agriculture, and the gradual depopulation of the areas referred to may therefore be taken as *prima facie* evidence of a serious decline of this important industry. Growth of population is effected by births and immigration; and decline of population by deaths and emigration. Rapid growth of population is taking place through high birth-rates in the districts of Northern and Eastern Bengal

where agriculture is flourishing. In Northern Bengal also, the rapid growth of population is partly due to immigration into areas where cultivation is extending. For example, during the decade 1901 to 1911, the net gain by immigration into Dinajpur was 173,563, "the immigrants" according to the Census Report being "mainly found in the Barind, where they are fast reclaiming the waste." In Jalpaiguri district also, there has been great immigration, the excess of immigrants over emigrants between 1891 and 1911 having been 315,016. In the Alipur subdivision during one decade population increased by 53·1 per cent. in Falakata and no less than 81·4 per cent. in the Alipur thana. This extraordinary growth of population is entirely due to the favourable agricultural conditions. "In the Alipur subdivision," says the Census Report, "cultivation is extending in every direction and there is a constant stream of immigrants attracted by the fertility of the land and the lowness of the rents."

58. Decline of rural populations is governed by unfavourable agricultural conditions. Burdwan district especially is an example of depopulation following upon agricultural decline. Between 1872 and 1881 the loss of population in 12 thanas of the Burdwan district amounted to 148,605 and a further loss of 10,499 occurred in 9 thanas between 1881 and 1891. After a slight recovery at the Census of 1901, the decline continued and the 1911 Census revealed a further aggregate loss of 31,150 in 12 out of the 17 thanas. The loss of population in Burdwan is mainly due to an excessive death-rate and the mortality is largely governed by the local agricultural conditions, as may be seen on comparing the estimated outturn of winter rice with the deaths occurring during the first six months after harvest. During the 20 years, from 1893 to 1912 inclusive, the outturn of the rice crop, which is the mainstay of the people, was 80 per cent. of the normal, the average deficiency being 20 per cent. In 10 out of the 20 years, the outturn exceeded 80 per cent., sometimes very considerably, and in 10 years the crops were much below this average. The aggregate mortality of the six months following harvest during the 10 years with good harvests was 185,793, compared with 271,756 for the 10 years with poor harvests, giving an average excess mortality of 8,596 for every poor harvest. Similar factors may also be seen at work causing depopulation in Birbhum. In Central Bengal, extensive migration as well as high mortality is causing a decline of population in many areas. During the decade 1901 to 1911,

Nadia showed an aggregate loss of 63,805 persons in 16 out of 21 thana areas, Murshidabad lost 26,245 in 9 out of 24 thanas and Jessore 72,024 in 14 out of 19 thanas. Turning to the figures for migration, we find that the three districts named have long shown a great excess of emigrants over immigrants, and the figures relating to agricultural conditions quoted below afford the explanation :—

| | Excess of emigrants over immigrants. | | Current fallow to net cropped area. | Average deficiency in crop outturn. |
|---|---|---|---|---|
| | 1901. | 1911. | Per cent. | Per cent. |
| Nadia ... ... | 64,727 | 62,126 | 54·6 | 34·3 |
| Murshidabad .. | 7,600 | 31,712 | 64·6 | 26·5 |
| Jessore ... ... | 24,098 | 13,533 | 13·3 | 24·4 |

59. In the light of the facts just stated and the mass of evidence previously quoted, pointing to the extraordinary agricultural value of river water and the disastrous effect on cultivation that always follows the shutting out of this water from the fields, the view of the economists who hold that populations decline as a result of industrial decay, is seen to hold good in the case of Bengal, so that there is justification for the belief that the growth of population in the rural areas is an index of the local agricultural conditions. It follows that the depopulation of deltaic areas that have been embanked is a direct result of an agricultural decline that has followed this embanking.

### 26—Probable Loss arising from Embankments in the Damudar delta.

60. Some idea of the monetary loss that has resulted from the shutting out of silt-bearing river water from agricultural lands may be gained by a consideration of the following facts. As regards Damudar water, all authorities are agreed as to its value for crops. In villages adjacent to the Damudar, cultivators say that their land when irrigated with river water yields 12 *maunds* of paddy per *bigha* whereas when cultivated with rain water alone the crop is only 7 *maunds*. The Triennial Revenue Report on Irrigation of the Public Works Department states that the result of crop experiments in connexion with irrigation by

the Damudar water from the Eden Canal System in 1901-11 showed that the average outturn per acre of irrigated lands was 25 *maunds* 12 *seers* of paddy and 37 *maunds* 12 *seers* of straw against an average of 16 *maunds* 6 *seers* of paddy and 25 *maunds* 18 *seers* of straw from non-irrigated lands. This shows an increased outturn of over 50 per cent. due to the use of river water. In a later report, the excess value of the crops from irrigated over non-irrigated land was given at about Rs. 31 per acre. The shutting out of the Damudar spill water from the eastern portion of its delta must therefore have occasioned enormous loss. There are about 2,108,173 acres of cultivable land in the present districts of Burdwan, Hooghly and Howrah. Of this probably not less than half lie within the area that used at one time to be naturally irrigated with the flood water of the Damudar in the same fashion as much of the Dacca district to-day is irrigated by the flood waters of the Padma, Meghna and Brahmaputra. Assuming that when the land received Damudar water the outturn of paddy from a half to one million acres of this area averaged 25 *maunds* per acre and that since the shutting out of Damudar water the outturn has fallen to an average of 16 *maunds*, the resulting loss in outturn would amount to anything from 4½ to 9 million *maunds* of paddy per annum. The loss must in reality have been very much greater than this, because the figures quoted make no allowance for land now lying fallow or going completely out of cultivation.

### 27—A Comparison with the Dacca District.

61. A better idea of the probable agricultural loss in Burdwan, Hooghly and Howrah may be gained by a comparison of the agricultural conditions of the area under discussion with those of the Dacca district. Assuming that the agricultural conditions obtaining in these three districts before the shutting out of Damudar water resembled those in Dacca during 1918-19, we should find that, in place of the 1,137,200 acres actually cropped in that year, there would have been no less than 2,042,104 acres under cultivation, with only 109,908 acres of current fallow against 777,500. If the yield per acre of the 2,042,104 acres assumed to be cultivated in these circumstances was equal to that of the 1,137,200 acres that were actually cropped, the total outturn of the area under discussion would have been nearly 80 per cent. greater than it is. But this estimate makes no

allowance for the valuable fertilising effect of Damudar water, which increases the yield per acre by over 50 per cent. Assuming that half only of the area was cultivated under the most favourable conditions and obtained the benefit of Damudar water, the total outturn from the 2,042,104 acres assumed to be cultivated would then have been 225 per cent. greater than that now yielded by the 1,137,200 acres actually cultivated. Supposing the crop was all in rice, the outturn of 1 137,200 acres at 10 maunds an acre would be about 421,185 tons; an increase of 80 per cent. on this would make the yield about 758,133 tons, and with a yield of 225 per cent. the figure would be 947,666 tons. With rice at Rs. 5 per maund, this latter figure would represent a total financial return of over 12¾ crores against a little over 5½ or, a difference of over 7 crores. This latter figure represents quite a moderate estimate of the gross annual agricultural loss occasioned by the shutting out of Damudar spill water from its delta.

### 28—An Alternative Estimate.

62. Another method of gaining an idea of the probable loss in agricultural outturn occasioned by the shutting out of Damudar water from the land in this particular area, is to take the case of Hooghly, estimating its probable outturn on the assumption that, prior to the embanking of the country, the district was as fertile and well cultivated in proportion to its size as the Dacca district is now. On a rough computation, the gross value of crops harvested in the Dacca district in 1918-19 was about Rs. 12 to 15 crores. This allows for a yield below the normal, the average deficiency in Dacca over a long series of years being 5·7 per cent. Hooghly district should give under similar conditions a gross return of the value of Rs. 4½ to 5 crores. But instead of the 2·1 per cent. waste and 5·0 per cent. current fallow that Dacca showed in 1918-19, Hooghly in the same year had no less than 11·8 per cent. waste and 28·3 per cent. current fallow. Moreover, the average crop deficiency in Hooghly is 20·6 per cent. against 5·0 per cent. in Dacca. The present agricultural return of Hooghly in 1918-19 can, therefore, at best, be little more than 50 per cent. of what it would be if its agriculture was as flourishing as that of Dacca. The agricultural loss occasioned to Hooghly district by the stoppage of natural irrigation with Damudar water, is now probably over Rs. 2 crores per annum.

### 29—An Estimate of the Loss in Western and Central Bengal.

63. We can only make a very rough guess at the total agricultural loss occasioned to the Burdwan and the Presidency Divisions by the embanking of the country. In the case of Central Bengal (Presidency Division), which is wholly deltaic, the gross agricultural return, on the basis of the Dacca district estimate, ought to be in the neighbourhood of 50 or 60 crores of rupees per annum; a very similar amount should be allowed for the Burdwan Division; and a total of between 100 to 130 crores of rupees per annum for both divisions. But in all probability the actual outturn is considerably less than half this amount; owing to the impoverishment of the soil, the lack of moisture and the local water-logging that has followed the embanking of the country and the shutting out of the silt-bearing river water. Taking Western and Central Bengal (the Burdwan and the Presidency Divisions) together, the present gross agricultural outturn is probably somewhere between Rs. 50 or 60 crores, or less than one-half of what it would be if irrigation with river water was made available. Formerly, very large areas in both of the divisions mentioned used to benefit by a natural process of deltaic basin irrigation with flood water in the same manner that Eastern Bengal does at the present time. But since this flushing of the country has been prevented, agriculture, health and prosperity have suffered, millions of lives have been sacrificed, thousands of crores of rupees have been lost, the people are sunk in poverty and a vast proportion of them suffer each year from recurring attacks of malaria.

## CHAPTER IV.

## The Effect of Embankments on Malaria.

### 30—How Embankments Increase Malaria.

64. The increase of malaria that almost invariably follows the embanking of deltaic areas in Bengal is due to the interaction of a number of factors, most of which have a definite bearing upon the breeding of anopheles mosquitoes. The construction of embankments themselves leads, in the first place, to a great amount of excavation and the resulting borrow-pits afford additional breeding places for anopheles. But, except in rare instances, excavations of this kind are of relatively small importance, because enormous numbers of *dobas* and ditches and excavations of all kinds already exist in the immediate neighbourhood of all villages situated in deltaic areas. This is owing to the fact that every house has to be provided with a high earthen plinth raised well above the level of the inundation. In areas also where the houses are built of mud, as is the case in many parts of Central Bengal, building operations always result in extensive excavations. Hence villages in the delta tracts are all potentially malarious. But ordinarily, however numerous and extensive the excavations and borrow-pits on a village site may be, they do not give rise to malaria so long as the greater part of the surface of the country is submerged by floods of river water during each wet season, for in these circumstances each hollow and depression is temporarily obliterated, so that anopheles mosquitoes cannot use them as breeding places. But should inundation cease or be prevented, every hollow, which can hold rain water, becomes a dangerous breeding place, and anopheles mosquitoes can thus multiply unchecked. Observations show that during the rainy season anopheles mosquitoes of various species, known to carry malaria, often occur in enormous numbers in the villages situated in embanked deltaic areas, whereas these insects are usually present in very scanty numbers at the same time of the year in areas that are actually inundated with river water. The inundation of the country during the monsoon is unfavourable to the multiplication of anopheles mosquitoes, in the first place, because flooding reduces the dangerous "water-edge" which affords safe cover for mosquito larvæ; in the second place, because

owing to the large surface exposed to the rays of the sun the temperature of the water tends to rise so as to be exceedingly unfavourable to the life of anopheles larvæ; and in the third place, because the physical and possibly the chemical character of river water is inimical to anopheles larvæ. Observations show that anopheles larvæ are rarely or never found far from the grass grown or woody edge of collections of water; that they cannot stand a temperature much above that of the wet bulb thermometer and are rapidly killed by a temperature of 104 degrees Fahrenheit; and that they do not flourish in water containing fine silt in suspension. River water in the flood season also contains a very large amount of dissolved carbon dioxide ($CO_2$) so much so that its reaction tends to become acid, and this possibly affords a further explanation of the fact that anopheles larvæ do not flourish in river water during the flood season.

### 31—Recent Investigations on the Breeding of Anopheles Larvæ.

65. Investigations by Hodgson and King serve to throw a new light upon the rationale of phenomena of the kind referred to enabling us to understand how irrigation may, in certain circumstances, reduce malaria, and why on the contrary a reduction of the surface water in deltaic areas may bring about an increase of the disease. The following passage is extracted from Hodgson's note in the proceedings of the Lucknow Sanitary Conference, 1914 :—

"Taking the mosquito in its larval existence, we found that the optimum temperature for anopheles lay between 68°-78° F. Temperature above 80 F. became more and more unsuitable, while temperatures of 95° to 104° F. were rapidly fatal. In nature during the monsoon at Delhi in August, and in Madras in November, we found the surface of pools to vary from 73° to 104° F., the difference being due to the following important facts :—

(1) The *coolest* pools were very small pools lying amongst grass.

(2) The edge of a pool in the day time is cooler than the centre.

(3) The surface layer is often 3° or 4° hotter than the water 4 or 5 inches down at midday.

(4) The water lying at the shallow edge, round grass stems, is the coolest part of a pool.

(5) When the average temperature of pools had risen to 90° or even 100°, falling rain both at Delhi and Madras was found to be 73° to 77° F. during the monsoon.

(6) The river at Delhi even after long drought never rose above 87° F. at midday.

*(7) Well-water varied from 80° F. to 82° F.*

*(8) The sea at Madras in the monsoon was 80° F.*

(9) Small hoof marks in grass might contain water 9° F. cooler than a large pool 6 inches away, particularly during hot dry weather.

"An anopheles mosquito lays her eggs in that type of pool which is coolest at the time. The struggle for existence rapidly increases above 80 F. and temperatures such as 104 F. are fatal to every single larva in less than 18 hours, though this is a temperature at which some pools have been found in nature. In the Terai in October, water varied from 65 F. to 78 F. on the two days we examined it, and anopheles were breeding in millions. The great destroyer of mosquito larvae is nature, and her principal means is raising the temperature of the water."

It will be seen from these observations that small collections of water and those possessing a large ratio of weedy edge are far more dangerous than large water surfaces, because they invariably possess a lower temperature much more suitable for mosquito larvae than the high temperature to which large collections of water speedily become raised. This fact helps to explain the beneficial effect of flooding upon the prevalence of malaria. When water is admitted in large amount to the surface of a low-lying country, all the small pools are converted into large ones; on the one hand the ratio of dangerous edge is greatly reduced and on the other hand the temperature of the water is speedily raised with the result that the output of anopheles mosquitoes is restricted.

### 32—Indirect Effect of Embankments on Malaria.

66. Embankments that prevent flooding may thus be a direct cause of malaria, but they also tend to increase the malaria of delta tracts in an indirect manner. The cessation of inundation, as we have seen, causes a decline of agriculture, leading to economic stress among the population. It causes also a coincident increase of anopheles mosquitoes leading to the spread of malaria infection. The final result is an extraordinary exaltation of malarial disease, signalised by the occurrence of a serious epidemic. This epidemic malaria in turn causes depopulation, partly by increased mortality and reduced fecundity and partly by stimulating migration. And depopulation introduces a further vicious cycle causing a still further increase of malaria and still greater depopulation, until in

badly affected localities the population is eventually either entirely obliterated or reduced perhaps to a tenth of its former number, the sites of once densely populated towns and villages quickly lapsing into almost impenetrable jungle.

### 33—Why the Danger of Embankments was not formerly understood.

67. When the embanking of the delta tracts was begun, first as a measure of flood prevention, as in the case of Burdwan, Murshidabad and Nadia, then for roads, as in case of Jessore, and finally owing to the construction of railways, few persons realised that the process was fraught with danger. Even after attention had been called to the outbreaks of fever that followed the construction of embankments, the term "water-logging" which was frequently employed without having been clearly defined appears to have led to a misunderstanding of the situation. In those days the cause of malaria was unknown, but medical authorities were wont to ascribe it generally to "water-logging," meaning thereby a super-saturation of the soil with water. Rajah Digambar Mitter, when seeking to explain the epidemics of malaria that occurred in association with the construction of embankments, suggested that they were due to "water-logging" produced by these embankments. By "water-logging," however, he appears to have meant "obstructed flow" rather than super-saturation of the soil. It may be remarked that the term is frequently used by Bengalis in the former sense at the present time. Obviously, obstructed flow may occur either in association with excess or as the result of deficiency of water; but in Bengal, it is deficiency rather than an excess of water that is especially dangerous, and that is concerned in particular with the obstructed flow so often observed in the case of the silted-up channels of malarious areas. When, however, the medical men and engineers, who were asked to investigate the epidemic fever, sought for evidence of water-logging, they naturally looked for evidence of the saturation of the soil, which that phrase ordinarily implies, and, failing to discover much evidence of this, they declined to admit that water-logging was the explanation of the epidemic fever; whereas, had they enquired into the question of obstructed flow and a reduction of the surface water in the affected tracts, they would have found, as in fact many of them did find,

evidence of this on all sides. Even in comparatively recent times, a similar misunderstanding has often prevented an appreciation of the real facts. Recently a serious increase of malaria in a village near the Sara Bridge followed the shutting out of flood water by the construction of an embankment. In reply to an appeal from the District Magistrate, the engineers who were responsible insisted that the village must in reality have become more healthy, rather than less so because. owing to the embankment, it was much drier than before. In this case it was true that the village was drier than formerly, but it was also true that the breeding of anopheles had been greatly increased in consequence of the numerous small isolated collections of rain water that had taken the place of the former general flooding of the village site, with the result that malaria had greatly increased.

### 34—The Effect of Superabundance of Water on Malaria.

68. As a matter of fact, few people are aware that for centuries it has been known that the partial drying up of large swamps often renders them intensely malarious, and that in low-lying deltaic tracts a heavy rainfall and the occurrence of inundations prevents malaria and serves to keep them healthy. "In some marshy countries," says Davidson, "a heavy rainfall diminishes the prevalence of fever by covering the marshy ground with a protective sheet of water. Thus, in the Netherlands, it has often been remarked that rainy years are healthy years, while hot and dry seasons are feverish." "Very heavy rain," says Scheube, speaking of conditions affecting malaria prevalence, "has a deterrent influence on naturally damp soil. . . At the height of the rainy season. . . in Deli in Sumatra (Martin). and New Guinea (Schellong), the minimum number of cases of illness is notified." He explains this by observing that "a thorough soaking of the soil is deleterious to the development of the mosquito." "In many regions," says Craig, "where abundant rains occur, malaria is rare, even though the anophelines are present. This is explained by the fact that in such regions the rains are so heavy and continued that the breeding places of mosquitoes are washed out and ova and larvæ do not have a chance to develop, or that no infected individuals are resident in the locality. In the former

instance an unusually heavy rainfall may act as a protection against malaria." Manson, too, has observed the same thing and explains it in the following passage :—

"In some places, particularly in those that are low-lying, flat and swampy, fevers of first invasion disappear almost entirely when the country becomes flooded. . . . . In some places, much rain will scour out the mosquite pools, in other places it will just fill them. . . . . The key to the explanation of the varying relation of malaria to rainfall is to be found in the influence of the latter on the local mosquito pools."

69. The passages quoted above show that it has long been recognized that in low-lying countries a superabundance of surface water, far from being harmful, may exert a beneficial influence upon malaria. And authorities like the late Professor Angelo Celli and Professor Julius Mannaberg have always regarded flooding or "covering by water" as useful measures for the control of the disease. The former author in his classical monograph on "Malaria according to the New Researches" refers to this method of combating malaria in the following words :—

"Covering can, so to speak, also be made with *water*. If a stratum of water be made to cover a malarious site, so long as the water remains at a constant level, there will be brought about a relative improvement. . . This submersion in certain cases is only relatively beneficial, and its real value will have to be tested in the light of the new theory regarding the origin and propagation of malaria by means of mosquitoes. Thus perhaps will be explained what seems to be a paradox, namely, that the suppression of an epidemic of aquatic origin is brought about by the presence of water."

### 35—Embankments a first step in reclaiming a delta.

70. The first effect of constructing embankments in low-lying areas subject to inundation from rivers is to reduce very largely the total volume of water present on the surface of the land during the actual flood season, which in hot countries is the malarious season. This reduction of the surface water causes a great increase of malaria. The second result is that, the amount of rain water, that is held up after the flood is over, and the water-level of the rivers has fallen, may be considerably increased because the embankments tend to check the "run off" from the land surface. This does not usually affect malaria very much, because the season of new infections is nearly over, but it damages agriculture. Embankments, therefore, cause an extraordinary change in the entire regime of a delta. Many deltas, it is true, have been reclaimed and put under pasture or dry cultivation ;

and this reclamation has necessitated the construction of embankments. But it has been necessary in all such cases to provide special systems of drainage, usually by means of pumps. Examples of this are to be seen in the case of the Po, the Rhine and the Scheldt, and in the Fen district of England. The construction of embankments is often therefore a first step in the reclamation of a delta. But deltas that have been embanked without any corresponding reorganisation of their drainage, are only partially reclaimed. The situation of the population of a delta that has been left in this condition is deplorable in the extreme. Agriculture is seriously interfered with. The cultivators cannot grow the same amount of wet crops as formerly, owing to the lack of fertilising river silt and the fact that in some portions of the country there is too little water while in others there is actual water-logging: and they cannot grow dry crops because drainage by gravity is not sufficient for this purpose. Above all the people are exposed to recurring attacks of epidemic malaria as a result of the partial reclamation of the country by the embankments.

### 36—Partial Reclamation of Low Lands always conduces to Malaria.

71. Throughout all ages history is unanimous on this point that the partial reclamation of swamps invariably leads to an appalling increase of malaria.

"No one in Holland," says Wilson, speaking of the influence of malaria in causing disease, "has any doubt as to the origin of this power, but ascribes it uniformly to the drainage of some lake. . It was even foretold by several writers that fevers would result from draining the Lake of Haarlem, as took place in the years 1608, 1641 and 1779 from draining several polders. At Haarlem the summer of 1779 was extremely hot and a fever epidemic appeared which continued for three years. It was ascribed to the draining of several polders." "So long" he adds "as the Lake of Haarlem was a lake, or mere, so long were its banks healthy. But drain it partially and you must be prepared for the result. There is no middle course. It must be arrested by the hands which drained or attempted to drain it and converted into healthy pasture land or a wheat field. . The effects of partial or incomplete drainage have ever been the same."

72. The influence of partially reclaiming swamps or lakes on the health of the inhabitants was frequently discussed during the last century, especially in connexion

with the draining of the low-lands of Biensten and de Wonner, etc. The reclaiming of the La Chartreuse swamp near Bordeaux is also a classical example. After the work was commenced in the summer of 1805, an appalling epidemic broke out which caused 18,000 cases of pernicious malaria and 3,000 deaths. A similar occurrence also took place in the neighbourhood of Peterborough about 1860, following the reclamation of the Whittlesea mere. In his report to the Privy Council on this outbreak, Dr. Paley remarked "The first effect of the improved drainage of the large Fen districts has been rather to increase the prevalence of ague." In Bengal, the construction of embankments in the delta tracts has been followed by similar results. But in this case the evil has been infinitely greater. In all the other instances mentioned, reclamation was finally completed, so that the reclaimed areas became rich farm lands, from which the local population eventually derived great benefit. But in Bengal there has been no attempt to turn the rice swamps into wheat land and pasture. On the contrary, natural irrigation with river water has been stopped and drainage obstructed. And the inevitable result has been agricultural deterioration and epidemic malaria. It must not be supposed that those responsible for the embanking of the country had any idea that such results would follow. They aimed at increasing the welfare of the community by preventing floods and improving communications But the disastrous results of this policy has at last become apparent, and every endeavour must now be made to prevent a continuance of the error and to remedy, as far as possible, the evils that have occurred through past mistakes.

## CHAPTER V.

### *Agricultural Decline and Malaria in Eastern Bengal.*

#### 37—The possible Extension of Malaria and coincident Agricultural Decline in Eastern Bengal.

73. The evils of endemic and epidemic malaria, agricultural decline and depopulation from which such a large proportion of the deltaic areas of Lower Bengal have long been suffering, and which have been shown in the present report, to be the direct outcome of the disastrous policy embarked on some seventy years ago, of embanking the country in every direction mainly for the purpose of railway and road construction, are serious enough to merit the most careful attention with the view of discovering an effective remedy. But before passing on to consider what that remedy should be, a note of warning must be sounded in respect to those parts of the country which have up to the present remained largely immune from the evils we have been discussing. The existence of malaria, agricultural deterioration and depopulation, especially in the Burdwan and the Presidency Divisions, has long been admitted, but unfortunately the explanation of these troubles has not as yet received official recognition, although, as has been shown by the extracts quoted, numbers of observers have from time to time pointed to the existence of embankments in the delta tracts as the cause of one or other of these evils. At the present time, heedless of danger, embanking of the country is being continued and railway and road construction is being rapidly extended. Moreover, the extension of communications of this kind is now being pushed forward with feverish activity in the most fertile and prosperous portions of Eastern and Northern Bengal, which have up to the present maintained an enviable preeminence for agricultural production owing to the favourable influence of the fertilising inundations which they still enjoy. If the facts that have been quoted in this note are correct, and the conclusions that have been drawn from them are sound, the further extension of embankments in the deltaic areas of Northern and Eastern Bengal without simultaneously providing for irrigation will be fraught with the gravest consequences not only to these areas themselves but to

the trade and commerce of Calcutta, the civil administration and prosperity of the country as a whole.

### 38—The Effect upon Calcutta and the Jute Industry of the Embanking of Eastern Bengal.

74. A consideration of the following facts will show that, quite apart from the question of malaria, this warning is needed. The manufacture of jute, as is well known, is now the most important industry in the province, and the export of raw and manufactured jute is its most valuable commercial asset. There are over 70 jute mills in the neighbourhood of Calcutta employing several hundred thousand workers; and the extension of this industry has been the most efficient factor in reclaiming many of the riparian municipalities from the ravages of malaria from which many of them were suffering up to a few years ago. The prosperity both of the city and its environs and of the port of Calcutta is largely bound up with the continued prosperity of the jute trade; moreover, the civil administration is also vitally interested in view of the fact that the export duty on jute contributes annually no less than Rs. 3,00,00,000 to the State Exchequer. The jute trade is dependent upon an abundant and cheap supply of raw material. At present over 60 per cent. of the jute grown in Bengal comes from the non-malarious eastern districts; Northern Bengal contributes over 25 per cent. of the supply and the Burdwan and the Presidency Division barely 10 per cent. Hence the jute trade largely relies upon the productiveness of Eastern Bengal; and to maintain the production of jute it is essential that the present extraordinary fertility of this particular area should continue. The fertility of Eastern Bengal, as we have seen, is almost wholly due to the inundations with silt-bearing river water which these delta tracts now enjoy.

"The plains of Eastern Bengal watered by the Brahmaputra" says Hunter "yield unfailing harvests of rice, mustard oil seeds, and the exhausting jute crop year after year without any deterioration." "Jute has long been one of the principal sources of profit to the cultivators of Eastern Bengal."

As far back as 1877, the Collector of Dacca reported that:

"The jute grown in Dacca alone and sold at Narayanganj put a sum of money into the hands of the cultivators sufficient to pay the rental of the whole district and leave a profit of from eight to thirteen lakhs of rupees."

In 1906 it was stated that, on a conservative estimate, jute brought not less than Rs. 4½ crores into the Dacca district and, it is possible, that the value of the crop may even have reached a figure as high as Rs. 5·4 crores. In 1913-14 the gross value of the jute crop of the whole province approximated to Rs. 70 crores.

### 39—Jute requires River Silt.

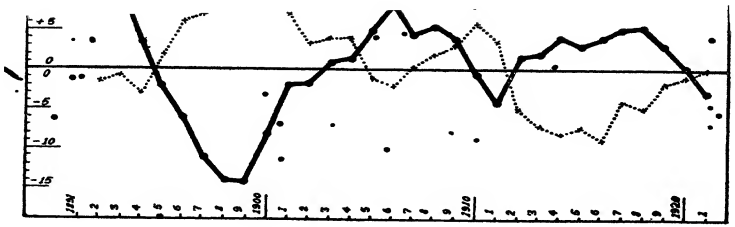
75. "Very little manure is given to jute," says Watt, "especially where silt deposit takes place. In fact the superiority of certain districts over others is largely a consequence of the heavy annual deposit of silt." The *Imperial Gazetteer* and the *Eastern Bengal and Assam Gazetteer* express similar views, the former stating that "jute is chiefly grown on land which is liable to be submerged when the plants have made some progress, for it is an exhausting crop on soils not benefited by inundation silt"; and the latter remarking "the crop is an exhausting one and the low lands which are annually flooded and fertilised by silt deposits from the rivers are therefore best suited for it."

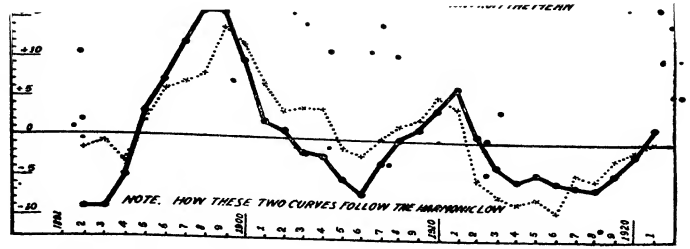
### 40—Jute an Exhausting crop.

76. "Jute is an exhausting crop" says the *Statistical Account* of the Pabna district, so that 'pulses cannot be sown in the cold season on jute land," and jute cannot be profitably grown for two years in succession on the same land."

"In the first year of its growth," says the *Statistical Account* of the Nadia district, "a bumper crop is obtained; in the second year the yield is somewhat less; and in the third year the quality as well as the quantity of the plant deteriorates considerably, the soil having become impoverished in consequence of the exhausting nature of the crop."

Views similar to those quoted above were also expressed in the report of the Jute Commission a number of years back. "I have no hesitation," states the Commissioner, "in saying that jute exhausts and impoverishes the soil to a much greater extent than the other crops. As to the degree to which soil is exhausted by the cultivation of jute, I am disposed to think that ordinary virgin land which has been broken up for a first crop of jute, will, in the second year, lose about 25 per cent. of its production power; and that, even though afterwards manured, the yield in the






## RICE HARVESTS AND BIRTHS IN CENTRAL & WEST BENGAL

QUINQUENNIAL MOVING AVERAGE OF BENGAL RICE PRODUCTION
QUINQUENNIAL MOVING OF THE RATIO BETWEEN THE BIRTHS IN EAST BENGAL AND THOSE IN CENTRAL & WEST BENGAL

EACH CURVE SHOWS PERCENTAGE DEVIATION FROM THE MEAN
BIRTHS ARE LAGGED ONE YEAR BEHIND HAVESTS

## RICE HARVESTS AND BIRTHS IN EASTERN BENGAL

QUINQUENNIAL MOVING AVERAGE OF BENGAL RICE PRODUCTION
QUINQUENNIAL MOVING AVERAGE OF THE RATIO BETWEEN THE AGGREGATE BIRTHS IN EAST BENGAL AND THOSE IN WESTERN & CENTRAL BENGAL

EACH CURVE SHOWS PERCENTAGE DEVIATION FROM THE MEAN
BIRTHS ARE LAGGED ONE YEAR BEHIND HAVESTS

## NATURAL INCREASE OF POPULATION AND RICE HARVESTS

QUINQUENNIAL AVERAGE OF RICE PRODUCTION IN BENGAL COMPARED WITH QUINQUENNIAL AVERAGE OF NATURAL INCREASE OF POPULATION IN CENTRAL & WESTERN BENGAL
NATURAL INCREASE — RICE HARVESTS +·····+

SHOWN AS PERCENTAGE DEVIATIONS FROM THE MEAN.
NATURAL INCREASE IS LAGGED ONE YEAR BEHIND HARVESTS. THE SCALE FOR NATURAL INCREASE IS DOUBLE THAT SHOWN FOR HARVESTS, (e.g. 15-30)

## NATURAL INCREASE OF POPULATION AND YIELD OF RICE PER ACRE

QUINQUENNIAL AVERAGES OF THE DIFFERENCES IN NATURAL INCREASE BETWEEN EAST AND WEST BENGAL COMPARED WITH THE QUINQUENNIAL AVERAGE YIELD OF RICE THROUGHOUT THE PROVINCE. SCALE OF NATURAL INCREASE IS TEN TIMES THAT SHOWN FOR YIELD PER ACRE. (e.g. 10=100)
NATURAL INCREASE SHOWN THUS — ACRE YIELD THUS ·—·

EACH CURVE REPRESENTS PERCENTAGE DEVIATIONS FROM THE MEAN

third year will be about one half of the first year's crop. It is from this conviction of the exhausting power of jute on the soil that this crop is so frequently shifted from field to field, and I can testify from my own observations and enquiries that, except in the case of *chars* flooded annually, and very low lands which derive similar benefits by drainage, it is in very few instances only that jute is grown on the same land for more than three years consecutively." "Jute grown on poor land is generally admitted to be of bad quality and the output is very low." The *Nadia Gazetteer* remarks that:

"The quality of the jute grown in Nadia district is inferior to that grown in the districts north of the Ganges. A further explanation as regards Nadia itself lies in the inherent infertility of the soil."

77. The foregoing quotations show that there are grounds for believing that in the absence of irrigation an abundant supply of good quality jute so necessary for the maintenance of the prosperity of the great Jute Mill Industry can be ensured only by a continuance of the inundation and silt deposit characteristic of the jute-growing areas of Eastern Bengal, and that the shutting out of these inundations from the country by the constructing of embankments will have the effect of seriously diminishing the output of jute that is so necessary to the well-being of the most important of the manufacturing industries of the province.

### 41—Threatened Reduction of the Jute Crop.

78. Should the existing supply of raw jute be seriously reduced, the effect will be ruinous in the extreme, not only upon the jute and allied industries, the commerce of Calcutta, the trade of its port but also upon the revenues of the Government and the general prosperity of the whole country. If embanking of the fertile delta tracts of Eastern Bengal is allowed to go on unchecked, such a reduction may occur within a measurable period of time. The normal area under jute in Eastern Bengal is 1,373,300 acres compared with 694,500 acres in Northern Bengal and a total of 353,000 acres in the Burdwan and Presidency Divisions. The former figure represents 14·7 and 9·6 per cent. of the net cropped area, the latter only 3·5 per cent. (viz., 1·3 per cent. in Western Bengal and 5·6 in Central Bengal). The outturn of jute per acre is admittedly higher in Eastern Bengal, and the quality of the fibre is usually considered to be better also. These differences are probably both due to the fertile character of

a soil annually enriched with river silt and an abundant supply of water in which to steep the fibre. The poverty of the soil in Western and Central Bengal necessitates a larger proportion of the cultivated area in these two divisions being devoted to food crops, a fact which probably accounts for the relatively small area apportioned to jute. The embanking of the land in Eastern Bengal will undoubtedly be followed by the rapid impoverishment of the soil in that area also which, in turn, will certainly compel the cultivators to put more of their land under food crops and less under jute.

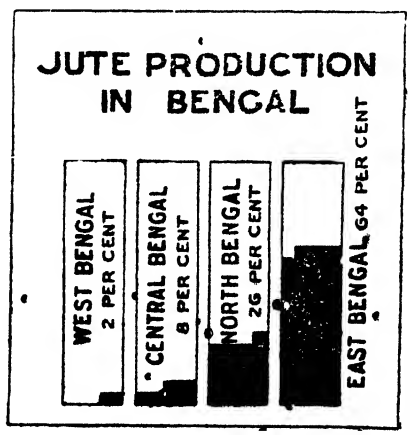
### 42—Present and Future Production of Jute.

79. The present estimated yield of jute per acre in the four divisions under discussion is :—

| | | |
|---|---|---|
| 3:2 | bales per acre for | Western Bengal. |
| 3:5 | ditto | Central Bengal. |
| 3:7 | ditto | Northern and Eastern Bengal. |

The total yield for the four divisions on these estimates would reach, in an ordinary year, the total given below, based upon the figures for 1918-19: —

| | | Bales | Proportion of total yield of 4 divisions Per cent. |
|---|---|---|---|
| Western Bengal | ... | 162,240 | 1·9 |
| Central „ | ... | 635,250 | 7·7 |
| Northern „ | ... | 2,156,730 | 26·4 |
| Eastern „ | ... | 5,194,430 | 63·9 |
| Total | ... | 8,148,650 | |



If it should happen that, owing to the lessened fertility of the soil and a corresponding lack of water, the outturn of jute from Eastern and Northern Bengal is diminished until it falls to the same proportion as that supplied by the other two divisions, the jute harvest of the former areas will be reduced by five or six million bales per annum. Even if Eastern Bengal is reduced to the condition of the Presidency Division, which as far as jute is concerned, is not yet quite so bad as that of the Burdwan Division, its jute harvest would be lessened by over four million bales. In view of the fact that nearly 64 per cent. of the total jute grown in the province comes from Eastern Bengal the disastrous effect upon the whole jute industry of an 80 per cent. reduction in the jute crop of this area will be apparent.

### 43—Threatened Agricultural Decline in Eastern Bengal.

80. A comparison of the following figures which relate to agricultural conditions in the three divisions under discussion will show that a catastrophe of this kind is by no means outside the range of probability : —

| | Total cultivable area. | Cultivable waste | Fallows | Net cropped | Twice cropped area. | Gross cropped area. |
|---|---|---|---|---|---|---|
| Western Bengal ... .. | 7,044,293 | 1 783,063 | 928,030 | 4,337,200 | 374,800 | 4,708,000 |
| Central ,, .. .. | 6 486,455 | 1,144,205 | 1,544,150 | 3,798,100 | 727,300 | 4,525,400 |
| Total | 13,530,748 | 2,927,268 | 2,472,180 | 8,135 300 | 1,102,100 | 9,233,400 |
| Eastern Bengal ... .. | 10,213,700 | 751, 63 | 371,747 | 9,090,709 | 2,218,700 | 11,309,409 |

The relative conditions of the three divisions may be judged from the following table :—

| | Proportion of waste to cultivable area. | Proportion of fallow to cultivable area. | Net cropped area to total cultivable area. | Proportion of twice cropped to net cropped area. |
|---|---|---|---|---|
| | Per cent. | Per cent. | Per cent. | Per cent. |
| Western Bengal ... | 25·3 | 13·1 | 61·5 | 8·6 |
| Central ,, ... | 17·6 | 23·8 | 58·5 | 19·0 |
| Eastern ,, ... | 7·3 | 3·6 | 89·0 | 24·4 |

Taking Western and Central Bengal together, 21·6 per cent. of the total cultivable area was lying waste in 1918-1919, 18·2 per cent. was current fallow, only 60·1 per cent. was actually cultivated and 13·5 per cent. of the cultivated area was cropped twice.

If cultivation in Eastern Bengal is reduced to the same deplorable state in which it now is in the two other divisions, the amount of waste land and fallow, respectively, will be greatly increased, the cultivated area will be greatly reduced and double-cropping of the land will become far less frequent than at present. The figures cited below show the present agricultural statistics of Eastern Bengal compared with the conditions that may be produced in the future if the suicidal policy of embanking the country is continued :—

| | Present condition of Eastern Bengal. | Possible future condition of Eastern Bengal. | Increase or decrease. | Percentage of increase or decrease. |
|---|---|---|---|---|
| | Acres. | Acres. | Acres. | Per cent. |
| Cultivable waste ... | 751,263 | 2,106,161 | +1,354,898 | +180 3 |
| Current fallow ... | 371,747 | 1,858,895 | +1,487,148 | +400 0 |
| Net cropped ... | 9,090,700 | 6,138,439 | -2,952,261 | -32 4 |
| Twice cropped ... | 2,218,700 | 1,227,244 | -991,456 | -44·6 |
| Gross cropped ... | 11,309,400 | 7,365,683 | -3,943,717 | -34·9 |

**44—The Effect of Agricultural Decline in Eastern Bengal.**

81. Should Eastern Bengal suffer an agricultural decline similar to that which has occurred in the Burdwan and Presidency Divisions, since these areas were deprived of enriching inundations, the resulting diminution of cultivation will be nearly 35 per cent. of the present gross cultivated area. But this figure by no means represents the whole reduction that would occur in the gross agricultural outturn. It takes no account, for instance, of the admitted fact that river water increases the yield of cultivated land by as much as 50 per cent., and that decreased fertility must follow the shutting out of this water from the fields. At present, according to the *Imperial Gazetteer*, the outturn of rice in the fertile swamps of Eastern Bengal is half as much again as in other parts of the province. Careful experiments in the area irrigated from the Eden Canal system also have shown that fields receiving river water yield 25 *maunds* of paddy per acre, whereas they give only 16 *maunds* per acre when cultivated with rain water. It may safely be assumed, therefore, that depriving the fields of Eastern Bengal of silt-laden river water will diminish their yield by 33·3 per cent. Hence we have to consider not merely the effect of a possible reduction in the gross cultivated area, amounting

to nearly 35 per cent., but the additional loss occasioned by a diminished yield from the 7,365,683 acres that would still remain under cultivation. In the circumstances stated, the total production of this latter area might conceivably be reduced to an amount equal to that now derived from only 4,910,456 acres, the loss being equal in amount to the total crops grown on 2,455,227 acres, or the third part of 7,365,683 acres. Adding 2,455,227 acres to 3,943.717 shown in column 4 of the above table, gives a total of 6,398,944 acres, which represents the possible loss of productiveness which might conceivably follow if agriculture in Eastern Bengal is reduced to a condition similar to that prevailing in the Burdwan and the Presidency Divisions. By assigning a hypothetical cash value to the produce of an acre, this possible loss can be expressed in terms of money. If, for example, the value of the present gross yield is estimated at Rs. 50 per acre, the monetary loss might be in the neighbourhood of 32 crores of rupees, but if the average value of the crops is put at Rs. 100 per acre. which is a more likely estimate at present prices, the total loss would be double this, or nearly 64 crores of rupees per annum.

82. The above estimate assumes a 33·3 per cent. reduction in outturn, resulting from the cessation of natural irrigation by river water in addition to a 35 per cent. decrease of acreage. But in place of this we may take another estimate. In Eastern Bengal, the average harvest deficiency over a long series of years is about 7 per cent. of the normal. But the mean average crop deficiency in Western and Central Bengal, when taken together, is about 22·2 per cent. Assuming that the shutting out of river water from Eastern Bengal would increase the average harvest deficiency from 7 per cent. to 22·2 per cent., the loss of crops occasioned on 7,365,683 acres would then represent a reduction in agricultural production equivalent to the yield of 1,119,203 acres. or nearly 10 per cent. of the present gross cropped area. Allowing 35 per cent., therefore, for land going out of cultivation, *plus* a further 10 per cent., for the loss of outturn owing to lessened fertility, it equals 45 per cent., a figure which represents the possible annual reduction in the agricultural outturn of Eastern Bengal. This would diminish the harvest to 55·0 per cent. of what it is at present. In other words, supposing the agricultural production of Eastern Bengal is now worth Rs. 113 crores per annum, the loss occasioned by reducing this area to the condition of the Burdwan and Presidency

Divisions would be more than Rs. 50 crores per annum. This figure, it may be observed, is about the mean of the minimum and maximum estimates of the loss previously given in paragraph 81.

The reduction of Eastern Bengal to a condition resembling that of the Burdwan and Presidency Divisions would probably entail the ruin of the jute industry, the commercial decay of Calcutta and the financial embarrassment of Government. But these are not the only consequences to be considered, for it is certain that, coincident with the agricultural decline of Eastern Bengal, a fearful extension of malaria would take place in the delta tracts of that division, at present largely exempt from the disease. A similar fate would also threaten the riparian municipalities adjacent to Calcutta, which owe their present comparative immunity from malaria to the mill industries established within the last 50 years. For, with the decline of the jute industry, these towns would suffer from economic loss and depopulation, epidemic malaria would become active again, and they would once more relapse into the condition of jungle, from which they have only recently emerged.

### 45—The Effect on Central and Western Bengal.

83. Under the conditions that have been pictured in the last three paragraphs, what hope would remain for the millions of unfortunate people in the malarious areas of Western and Central Bengal? Immediate relief can only be given to the affected tracts by lavish expenditure on quinine, the provision of an adequate health staff and the establishment of co-operative anti-malarial societies, pending the carrying out of the huge schemes of irrigation, which alone offer an effectual remedy for the associated evils of agricultural decline, epidemic malaria and depopulation. But how will the money required for these objects be found, should the agricultural prosperity of that portion of the province, which is the main source of the country's present wealth, be destroyed, or even seriously injured, as is certain to be the case if the former policy of embanking the delta tracts is to be continued? It is of course unnecessary to press this point; the mere asking of the question is enough to show how much the future welfare of the country depends upon the continued health and prosperity of the only part of the province as yet largely exempt from the attacks of malaria.

## CHAPTER VI.

## How to prevent the extension of Malaria in Bengal.

### 46—The Remedy for Malaria in the Delta Tracts of Bengal.

84. The facts discussed in the earlier portions of this report show that the great increase of malarial disease that has taken place in many deltaic areas in Bengal is inextricably bound up with a coincident decline of agricultural production owing to diminished natural irrigation and impoverishment of the soil. The common origin of these associated evils is to be sought in the decay of the river systems of the delta tracts, accelerated by the embanking of certain main channels, the mischief being further greatly intensified by the construction of thousands of miles of raised roads and railways. At present the natural divisions of Western and Central Bengal are chiefly affected; but certain deltaic tracts in Northern Bengal have long been suffering in a similar manner; and vast areas in Eastern Bengal that have so far remained comparatively immune both from malaria and from the agricultural decline that invariably accompanies an increase of the disease in rural areas, are now seriously endangered owing to the rapid extension of embanked communications of all kinds. At the present moment, therefore, Bengal is faced with two problems: (1) how to avert the threatened extension of malaria, especially in Eastern Bengal; and (2) how best to remedy the malaria already existing both in that and in the other natural divisions of the province. The present chapter will deal with the first of these problems.

### 47—How to avert the Extension of Malaria in Healthy Deltaic Areas.

85. Deltaic areas that are as yet free of malaria are characterised by possessing rivers that are still active, spilling over their banks in the flood season and distributing their water through the numerous channels which intersect the country. As a result of the free supply of flood water, these areas are subject to inundation, but as they have few embankments, the water passes freely over the surface of the country doing no harm and bringing wondrous fertility to the soil. At the end of the wet season, the river levels fall and the flood water flows away from the surface of the

land leaving the soil well-drained and healthy, alike for crops and for human beings. It must always be remembered that these favoured localities, although they now enjoy a wonderful immunity from malaria, do so only because of the superabundance of surface water that covers the country during the wet season. Moreover, they are in a state of unstable equilibrium. For if conditions in respect to the flow of surface water over the country are interfered with so as to diminish the normal amount of flush and permit instead of the formation of small pools of relatively stagnant rain water so favourable to the breeding of anopheles mosquitoes. these healthy prosperous districts are capable of becoming intensely malarious. To prevent deltaic areas of this kind becoming malarious, the integrity of the rivers and smaller water *channels must be maintained, their respective spill areas* preserved, and normal inundation encouraged. Above all. the erection of embankments of any kind, whether for railway or road communications or other purposes, must be absolutely prohibited until such time as it is possible to devise a method of construction that will not interfere with the natural irrigation or the drainage of the country, and will neither damage agriculture nor the health of the community. The consequences of embanking deltaic areas are so exceedingly serious, both to cultivation and the public health, that once the danger has been recognised, the obvious course to follow, if these consequences are to be averted, is to stop the further construction of embankments. But action in this direction must be combined with a number of other measures if it is to do more than postpone for a short period the threatened evils of malaria and agricultural decadence. It will be necessary, for example, to examine the rivers and other water channels with a view of adapting them, if possible, both for irrigation and for purposes of communication. In the latter connexion it must be remembered that it is often the urgent demand for improved communications that has led in the past to the heedless embanking of the country, a process fraught, as we have seen, with results disastrous alike to health and agriculture.

The systematic examination of the rivers and watercourses in every district must be further supplemented by a survey of their local spill area and the lines of interior drainage. All embankments that already exist must also be carefully scrutinised with a view to determining what effect they have upon the natural irrigation and drainage

of the locality and whether the water-ways provided are sufficient for this double purpose. Lastly, the movements of the ground water must be watched in order to determine the level of the local water table and its seasonal variations, and to discover what influence these fluctuations have upon the growth of crops and the condition of the public health.

### 48—Summary of Measures required in Relatively Healthy Deltaic Areas.

86. Briefly summarised the measures that must be adopted to avert the spread of malaria in all districts possessed of healthy deltaic or sub-deltaic areas are as follows :—

(1) Prohibition of further embankments.
(2) Survey of existing embankments and their waterways.
(3) Survey of river channels and other water-courses.
(4) The mapping out of local spill areas and lines of drainage.
(5) Improvement of existing water channels.
(6) Examination of the local water-table.

In addition to the measures enumerated above, an attempt must also be made to determine, as accurately as possible, the existing conditions in respect both to malaria and agriculture. Much of the work thus briefly outlined can be undertaken immediately by the existing staffs of engineers, overseers and sub-overseers and the health officers employed by district boards. Such further assistance as may be necessary should be provided by Government under the direction of the respective departments of Irrigation, Agriculture and Public Health.

### 49—Prohibition of Embankments

87. The evidence incriminating embankments as the cause both of agricultural decline and increased malaria is so overwhelming as to warrant immediate action to prohibit the construction of any new embankments. But whether this can be done under existing legislation is doubtful.

Section 76 of the Bengal Embankment Act, 1882, reads as follows :—

(*a*) Every person, who in any of the territories to which this Act extends, without the previous permission of the Collector, shall erect any new embankment, or shall add to any existing embankment or shall obstruct or divert or cause or wilfully permit to be obstructed or diverted, any water-course, if such act is likely to interfere with, counteract or impede any public embankment or any public water-course ;

(*b*) every person who within the limits of the trac. included in any prohibitory notification under section 6, without the previous permission of the Collector, shall erect, or cause or wilfully permit to be erected, any new embankment. or shall add to any existing embankment, shall obstruct or divert or cause or wilfully permit to be obstructed or diverted, any water-course ; and

(*c*) every person who shall abet any such act as is mentioned in clauses (*a*) and (*b*),

shall be liable. on conviction, to a fine not exceeding five hundred rupees or in default of payment to imprisonment of either description for a period not exceeding six months.

But although clause (*a*) of section 76 appears to cover the creation of new embankments, section 6 of the Act which defines the powers of a Collector makes no reference to the prohibition of embankments. If it is feasible, however, to prohibit the construction of new embankments under the Act, orders on this point should be issued forthwith. The temporary prohibition of new embankments, whether for road or railway construction and, except perhaps in very special circumstances, for flood prevention also, is not likely to cause serious damage or much inconvenience ; while on the other hand it may avert much future evil Immediate action can do no harm whereas delay is dangerous. If action is postponed pending a full discussion of the question, great harm may be done before a final decision is arrived at.

### 50—Emergency Legislation.

88. Supposing immediate action to prohibit embankments cannot be taken under existing Acts, emergency

legislation will be necessary. This legislation should be designed to prevent the further embanking of the country, pending the carrying out of such further investigation as Government may consider necessary. Unless precautions of this kind are taken, there is a risk of embankment construction being pushed forward rapidly in anticipation of future action by Government.

### 51—Roads, Railways and Embankments a Necessity.

89. In order to avoid misunderstanding, it is just as well to point out that the prohibition of embankments is suggested as a temporary measure only. It is aimed at preventing that unnecessary damage to the country which is bound to occur when embankments are constructed, as they have been in the past, without due regard to the fundamental needs of agriculture and the public health. Railways and roads have played an important part in the social and commercial organisation of the country, and will continue to do so and they will be needed in increasing numbers as development proceeds. Even Romesh Dutt, who was no lover of railways, after discussing inland navigation, admits that "the present railway system ministers to the wants of commerce much more effectually."

Railways, when properly designed with due regard to the physical peculiarities of deltaic areas, so as not to interfere with the irrigation and drainage so vital to their agricultural prosperity, are of inestimable benefit. Lower Egypt, the delta of the Nile, is a striking example of this. This tract of deltaic country is barely half the size of the Presidency Division, and contains 3,100,000 acres of cultivation. But it possessed in 1911 no less than 2,400 miles of railway and 1,250 miles of raised roads. This net-work of communications has its proper place in the scheme of things. Agriculture and irrigation are recognized as being of vital importance to the well-being of Egypt and in consequence take precedence over everything else, the interests of railways being entirely subordinated to them; and any one who dared to suggest that communications should be given primary consideration over irrigation would be looked upon as fit inmate for a lunatic asylum.

But schemes of irrigation should always include improved communications. Irrigation projects also require the embanking of the rivers in order that they may be

adequately controlled and their waters properly utilized. Railways, roads and river embankments are necessary therefore and must be provided for if future progress is to be assured, always remembering that they must take their proper place in the whole scheme of organisation.

When Sir Arthur Cotton was laying out systems of irrigation for the deltas of Tanjore and Godavari, raised roads and bridges were included in the estimates of the work. Thus, in Tanjore, with its one million acres of irrigated land, no less than one thousand miles of raised roads and many hundreds of bridges were provided. In the original project for the Godavari delta also, it was stated that both river embankments and a system of raised roads were among the essential requirements, the latter being especially necessary "to allow of the conveyance of produce to the markets and to the coast through a country which is otherwise, from its nature, impassable in the rains"; and the estimates allowed for an expenditure of 17½ per cent. of the total cost on the construction of roads and bridges. Similar considerations must apply in the case of deltaic tracts in Bengal. When once the more pressing needs of cultivation have been looked to and agriculture preserved and restored, the question of increasing the number both of roads and railways must receive attention.

### 52—Survey of Existing Embankments.

90. It is probable that some information in regard to embankments is already available in every district; but it is doubtful if there is anywhere a complete record with full particulars of the various types of embankments that exist. Obviously such a record is necessary, and it must include detailed information regarding the number, character and size of the water-ways, and the areas within the sphere of influence of any particular length of embankment. In order to obtain this information, a preliminary survey must therefore be carried out in each district of all existing major embankments, including those for flood protection and for communications, such as railways and roads. A more detailed survey should afterwards be undertaken to supplement the information previously obtained. This latter survey might be carried out simultaneously with the suggested examination of water-courses and spill areas and the preparation of drainage maps.

The preliminary survey of embankments need not take long and might even be completed in one dry season.

It will afford valuable information on such points as the relative height of embankments, the number and size of the water-ways, the signs of scour at bridges and culverts, the presence of breaches and the evidence of previous impounding of water, and deposition of sand and silt. Data in regard to all these matters should be collected and recorded for future use. This initial survey during the dry weather must be supplemented by a subsequent examination during the flood season. The latter will be necessary in any case in order to obtain the requisite information in regard to "run off" and drainage; water-courses and their spill areas; and the effect of embankments in obstructing "run-off" and restricting "spill."

### 53—Water-ways in Embankments.

91. Certain special questions that arise in connection with embankments require to be carefully investigated. It is often supposed that the embankments of roads and railways do little or no harm if what is termed "*a sufficient number*" of water-ways is provided. But although bridges are always necessary where an embankment crosses a definite water-way, for the preservation of the embankment itself, the more or less haphazard provision of an extra number of culverts beyond those required for this purpose is an expedient of very doubtful value. Culverts may, of course, prevent the impounding of water and the drowning of crops but, on the other hand, they may increase the capacity of previously insignificant water-courses or lead to the formation of new ones. The effect of this is to cause the rapid removal of water from the fields; both those situated above and also those below the embankment being affected As a result water which would otherwise often be retained on the fields to the greatest benefit of the crops is rapidly removed from the surface of the country. A multiplication of culverts, while encouraging the removal of surface water from one area, may therefore seriously interfere with the natural irrigation of another. In this connexion, it must be remembered that drainage of the soil, so valuable from an agricultural point of view, consists in the removal of excess of sub-soil water Surface drainage may sometimes be required to prevent the drowning of crops; but unless it is carefully regulated. it may do immense harm by soil denudation and the washing away of valuable materials required for plant growth.

### 54—Effect of Embankments in causing Freshets in Rivers and Streams.

92. The possible effect of embankments in causing abnormal freshets in rivers and streams and so producing such various evils as "wash outs" at bridges and culverts, or the deposit of sand on lands in the neighbourhood of streams and rivers, also requires investigation. Embankments at right angles to the general slope of the country almost certainly tend to increase the discharge of water in existing channels. Water that in ordinary circumstances would pass from field to field over the whole surface of the country is diverted either to the right or left in a line parallel with the embankment until it finds an open water course through which it can escape, greatly increasing its storm-water flow. The whole system of natural flow across country is thus interfered with and the consequences are often disastrous both to health and agriculture for the reasons explained elsewhere in this note. The whole of this question requires careful investigation.

### 55—Effect of Embankments on the Water-table.

93. Little or nothing is known as to the influence exerted by embankments on the level of the water-table. It is recognized that variations in the height of the sub-soil water level have an extraordinary influence upon growing crops, and a corresponding correlation has often been observed between a high sub-soil water level and malaria prevalence. Embankments that impede "run-off" and stop drainage may cause a rise in the level of the sub-soil water, while those that shut out flood water undoubtedly restrict natural irrigation, and may be found to lead in certain areas to an excessive reduction in the height of the water table. Information in respect to both these points is urgently required, and data in regard to them should therefore be collected in the course of the proposed survey of the water-table.

### 56—Survey of River Channels and other smaller Water-courses.

94. A survey of all existing water-courses in every district is essential. In valleys and up-lands water-courses serve as drainage channels but in deltaic areas they are irrigation channels at one season and drains at another. If of sufficient size and depth water-courses may also provide useful means of communication and so facilitate cheap

transport. Water-courses require to be examined therefore from these three points of view : (1) drainage, (2) irrigation and (3) communications. As regards drainage, little needs to be said, because it is not this function that is likely to be overlooked. But it is necessary to emphasize the importance of water-courses from the point of view of irrigation and transportation, because unlike what has happened in the deltas of other countries these two important functions have been grievously neglected in the deltaic tracts of Bengal. In the great deltas of China, irrigation has a very extended and general distribution and it is said the most scrupulous care is taken to save and utilise every source of water in cultivation ; and to such good effect that in Southern and Central China it is estimated that an acre of land is made to support from three to five persons.

"In the province of Ningpo, Fo-Kien and Shanghai" says King "the water is generally taken from small ditches led out from streams or larger canals. It is said that in many parts almost every farm is supplied from canals or shallow laterals which are 2 or 3 miles long and from 10 to 30 feet wide, leading out at right angles from the main canals often from 200 to 400 feet apart. In the province of Fo-Kien where the rainfall is both quite large and well distributed, irrigation is still practised but as a means of increasing larger yields rather than a necessity." Conditions are very similar in the deltas of Siam. Consul-General Jacob T. Child states that, "about one-half of that country is under cultivation and of this four-fifths are irrigated, much of it for rice. The fields are supplied with water from canals, which branch out from the rivers in all directions, and the main lines are constructed by the general Government but those supplying the individual fields directly, are made by the individual land owners." The countries mentioned closely resemble many parts of Bengal both in their physical configuration and in their agriculture ; and they appear to offer an example of successful irrigation that might well be imitated with advantage, especially in the deltaic portions of the province. To this end, a survey of the existing water-courses in every district of Bengal is an imperative necessity both in the interests of irrigation and the improvement of agriculture and for the promotion of the general welfare of the whole population, by preventing the further extension of malaria. For this latter purpose, it is essential that information should be obtained in regard to the character of the water carried by the various channels in the flood season. Observations have shown that malaria is least prevalent in areas where the streams contain silt-bearing water derived from the great rivers. It is this silt-laden water also that is most valuable for crops. Streams and khals containing muddy water of this kind are obviously in vital connexion with active rivers, whereas those which carry only clear water are probably mere drainage channels. The proposed survey must take careful account of these facts. When it is completed, it should provide materials for a map of every district and the entire province in which living delta areas are clearly marked out from those parts in which the active circulation of flood river water has already ceased.

### 57—Water Transportation.

95. Only second in importance to irrigation is the question of transportation. Deltas are naturally well situated as regards water communications and in the deltas of almost every civilized country special attention has been paid to developing facilities for water transportation. Holland, Belgium and Italy afford striking examples. In Egypt we read that "boat building is the principal industry in the country and navigation employs more hands than anything except agriculture. The country, moreover, is flat and the current generally in one direction and the wind in the other, so that navigation is easy. All tolls were removed in 1904 from bridges and locks and navigation made free everywhere by Lord Cromer." Even the deltas of China are well-provided with a net work of navigable canals. "China" says King "dates its early enterprises of irrigation and transportation by water far back in antiquity, for she has numerous canals, some of them the most stupendous work of the kind ever undertaken. The Great Imperial Canal has a length of 650 miles and connects the Hoang-Ho with the Yang-tse-Kiang. It has a depth seldom exceeding 5 to 6 feet and in it the water moves at the rate of 2½ miles per hour. In its path there are several large lakes and across these the canal is carried on the crest of enormous dykes."

From the point of view of transportation, therefore, a survey of all the channels of the delta tracts is urgently required, and should be undertaken in the interest of inland navigation, whether for small boats or for larger vessels. It must not be supposed that this has no connexion with malaria. In every part of Bengal, the condition of the water-ways has an immense bearing on the question of malaria, and one of the best ways of keeping delta tracts healthy is to preserve the channels and use them both for irrigation and navigation. The malarious northern portion of Faridpur district, where there are roads and railways, exhibits a striking contrast with the healthy south-western area where the rivers and streams are very numerous and serve every village throughout the year and where all trade is carried by water. The late Major J. C. Jack, I.C.S., in his study of the economic life of a Bengal district, says "if a traveller walks through the northern part of the district in January and February and on to the south-west, he cannot fail to be struck by the contrast between

the two. The one region shows no visible signs of prosperity and appears to be completely stagnant. the other is full of movement, the markets are crowded and ply a thriving trade, the rivers and streams are full of boats at all hours of the day and the people generally show every sign of alertness and prosperity."

The question of improving facilities for the inland navigation of Bengal has been discussed time and again, but up to the present little has actually been done for the delta water-ways. "As early as 1828" says Romesh Datta "H. F. Pinsep, then Secretary, submitted an interesting note on the subject. There was no river in the world, he said, except those of China, on which there was so large a navigation as the Ganges. Thirty thousand boatmen found their livelihood on that river as far back as 1780 and the number had since increased. Everybody has been struck by the constant succession of boats moving up and down, the river never appearing for a moment altogether clear; and as this is the same at all seasons and in all places it leaves an impression of the extent to which this magnificent stream ministers to the wants of commerce and of the traveller such as defies an attempt at computation."

"There is no province" says the *Imperial Gazetteer* "in which facilities for navigation are so likely to be appreciated as in Eastern Bengal, with its dense population, its thriving industries and its innumerable river channels. There is great scope for further extension of inland navigation in this tract; and if the works will not prove directly remunerative they are not likely to impose a heavy permanent charge on the State, while they will be of great value in increasing the wealth of the community." The time has now come for something more than talk. From the point of view of malaria and agriculture as well as navigation, it is essential that the improvement of the water-ways should be undertaken without delay. Obviously, before the necessary improvement can be effected a survey of existing watercourses must be made. Such a survey in respect to the smaller channels may be initiated at once by district and local boards pending the examination of the larger rivers which can be carried out most efficiently by a Government department.

### 58—Local Spill Areas and Lines of Drainage.

96. The question of spill areas and lines of drainage is bound up with the regime of delta channels; and an

adequate survey of the latter necessitates the careful examination of the former. While it is possible to get a certain amount of useful data regarding the larger water-courses, at any time of the year, accurate information in respect to spill areas and lines of drainage can only be obtained during the flood season. Over a hundred years ago Rennell prepared a small map showing the portions of Bengal subject to annual inundation. In recent years an attempt has been made in connection with a malaria survey of the province to form an idea of existing conditions. But the available information is very scanty and the record is by no means complete. The time has now come to secure a more accurate idea of this important subject for there is ample evidence proving that inundation with spill water from the rivers has a most important bearing upon the allied question of agricultural prosperity, the integrity of water channels, the prevalence of malaria and the maintenance of the public health generally. The information that is needed can only be obtained by systematic surveys of the spill areas of every district in which deltaic conditions obtain. A survey of these spill areas and their lines of natural drainage should therefore be undertaken with as little delay as possible. As in the case of the survey of embankments and minor water channels, this work can best be taken up by the local engineering staff employed under district boards, assisted where necessary by officers from the Irrigation Department of Government.

### 59—The Preparation of Drainage Maps.

97. The preparation of drainage maps on the lines suggested by the late Sir Edward Buck, K.C.S.I., should be undertaken in every district as part of a general programme for the prevention of malaria and agricultural decline. Sir Edward Buck's method was as follows :—

"It was the duty of every patwari (village record-keeper) to mark on each field in the map by symbols or figures the nature of the soil, the rate of rent, character of irrigation and so on. He was required to add an arrow, showing the main drainage lines which carried the drainage water out of the village. When the village maps were placed alongside each other the drainge lines of any given tract could be easily drawn."

"It would seem to be difficult", says Howard, "to improve on Sir Edward Buck's method of constructing drainage maps and it is fortunate that this economical system is available. Wherever the country has been surveyed, the 'run-off' could be marked on the map and the drainage lines determined. The utility of such maps in India at the present time does not end with drainage schemes.

They would prove of service in many other aspects of the economic development of the country. They could be made use of in laying out new roads and new railways. Similarly, these drainage maps would be useful in irrigation works and indeed in the United Provinces they have been employed successfully for many years. Other uses suggest themselves, such as town-planning schemes, malarial studies and projects connected with rural sanitation. In the general administration of the country, good drainage maps, on a suitable scale, would be most valuable. All kinds of questions arise from time to time which have to be settled by District Officers and which involve the rights of others and the well-being of the country Drainage maps in many cases would be of great help in deciding many problems relating to land, to water, to communications and to town planning."

Drainage maps of the kind referred to will be invaluable in connexion with the proposed survey of embankments, water-courses and spill areas. Efforts should therefore be made by district and local boards to prepare maps on the lines indicated above of as many areas as possible during the approaching wet season.

### 60—The improvement of existing Water-channels.

98. In a few districts sums of money are already allotted every year for the improvement of khals and water channels. This is a move in the right direction, it can rarely do harm and may be of great service and should therefore be encouraged by Government. But no really adequate scheme of improvement of the main channels can be undertaken in the absence of comprehensive surveys of the larger rivers and the smaller water courses such as has been proposed in a previous paragraph. It is probable that in many districts schemes for the improvement of khals and other channels have been from time to time prepared and submitted to district boards for consideration. Pending the completion of the surveys referred to, district boards might, however, be asked to re-examine any projects of this kind with a view of carrying out the necessary works if on investigation the schemes appear to be feasible.

### 61—Survey of the Water-table.

99. Apart from a few scattered observations on the sub-soil water-level, that have been recorded from time to time in various scientific journals and reports, little is known of the water-table in various parts of Bengal. At

the present moment certain investigations in this connexion are being made in the Burdwan district. The method employed is the direct observation of the water level in a number of wells situated in different localities. Sir Leonard Rogers, I.M.S., drew attention some years ago to the correlation to be observed between the height of the ground water and the prevalence of fever and splenic enlargement; and the present enquiry in Burdwan is being carried out primarily at his suggestion.

*It is probable that throughout the deltaic tracts great fluctuations take place in the height of the water-table at different seasons of the year. Major (now Lieutenant-Colonel) F. C. Hirst has recorded differences of level in the same year at the same place as great as 27·5 feet. The* level of the water-table may also vary from year to year. Differences of nearly 20 feet have been observed at one place in the same month in different years. The yearly rise of the rivers and the rainfall are undoubtedly the factors exerting the greatest influence upon the height of the water-table; and annual and seasonal variations are mainly governed by these two factors. But it is probable that local conditions have also a very marked effect upon the level of the water-table. It is conceivable, for example, that the presence of embankments may in certain circumstances increase and in others reduce the mean height of the water-table very considerably, and modify the normal seasonal fluctuations in the one direction by the shutting out of flood-water and in the other by the checking of "run-off".

Besides the influence, which a high sub-soil water-level is supposed to exert on the prevalence of malaria, an influence which is now-a-days generally explained by its relation to the occurrence of surface pools of water favourable to the breeding of anopheles mosquitoes, it has long been recognised that it exerts a very marked effect upon the fertility of the soil. Agricultural experts have paid considerable attention to this question, and numerous observations have been put on record to show that, while water-logging may reduce the outturn of crops very greatly, a reduction in the height of the sub-soil water may sometimes increase the yield in a remarkable manner. As regards the effects of water-logging, Howard has shown, for example, that at Pusa even partial water-logging reduced the wheat crop by over 50 per cent.

In Egypt, experiments have been made to determine the relation between the height of the water-table and

the yield of cotton, and the conclusions arrived at were that, ordinarily as the thickness of the layer of soil above the water-table increases there was a steady increase in the yield of cotton up to a certain point, after which the yield remained constant. Down to a level of about 6 feet or so below the ground, a 39 inch decrease in the height of the water-table was followed by an increase of nearly 600 lbs. of seed cotton per acre. The yield of those plots where the water-table was on the average below 6 feet 6 inches from the ground surface was 1·75 times as great as the yield from plots where the water was less than 39 inches from the surface. It was further discovered that the general production of the individual cotton plants in regard to the number of flowers, the percentage of flowers which became ripe bolls, and the lint weight per boll, the height, the weight of a single seed and the number of seeds per boll, was increased as the level of the water-table was reduced.

The possible effect of the sub-soil water level on malaria and its undoubted influence upon soil fertility and crop outturns, point to the necessity of carefully investigating the water-table in every district. The simplest method of making observations is to record the height of the water in wells, and the corresponding level of the water in rivers and streams. In Egypt, where extensive studies of the water-table of different areas have been made for many years past, pipes have been sunk to a moderate depth in many areas, for the express purpose of studying the movements of the sub-soil water. In addition to taking water levels, investigation into the character of the ground-water has also been undertaken, frequent chemical analyses having been made with a view of comparing the saline content of the water in one area with that of another, and correlating it with corresponding analyses of the soil. In the present case all that is required at the moment is accurate information regarding the maximum, the minimum and the mean height of the watert-ables in a number of districts.

When this information is obtained, it will be possible to compare it with data regarding inundation, rainfall, malaria and agriculture, so as to discover what correlation there may be; and whether any difference in the level is to be observed in the case of healthy and prosperous areas, as compared with those in which malaria has become prevalent and agriculture has declined.

### 62—Malaria Survey of Relative Non-Malarious Districts.

100. In order to map out roughly the relatively healthy deltaic areas in any district and differentiate them from those that are already seriously affected with malaria, a complete malaria survey is not absolutely essential. Valuable information can be obtained without great difficulty by a study of the census reports, the vital statistics and the returns of cases of sickness admitted for treatment at the various dispensaries; and this can be supplemented with estimations of the splenic index in various localities. The census returns show the relative increase of population in thana areas. For our present purpose, areas in which the increase of population has approximated to 10 per cent. in the last decade may be considered "healthy" without further investigation. If the increase has been less than this the birth-rate, death-rate, and fever death-rate for the past 10 years must be examined. If there is only a small excess of births over deaths and the fever death-rate has shown a tendency to rise, the fever index of the area must be examined, provided there is a local dispensary or dispensaries from which data for this purpose can be obtained. The "fever index" as defined by Sir Ronald Ross is the ratio of fever cases to the total admissions for all kinds of sickness. The number of new admissions only, both of fever and of total admissions, is taken into consideration for the purpose of preparing the "fever index."

Every district possesses a number of dispensaries. By calculating the fever indices of each of these dispensaries, a rapid estimate can be made of the relative amount of malaria in the various localities they serve. When the figures from each dispensary have been obtained, they may be noted on a map. Maps must be prepared of each district showing (1) the increase of population in the thana areas, (2) the excess of births over deaths, (3) the relative fever death-rates, and (4) the fever indices obtained from the dispensary figures. The information obtained in this way must be further supplemented by obtaining the spleen indices of groups of villages at different points throughout the district. The spleen index is obtained by examining a number of children between the ages of two and ten years, recording the numbers examined and those showing definite enlargement of the spleen on palpation of the abdomen. The ratio of the latter to the total number of children examined is the "*spleen index.*" Besides noting actual cases of splenic enlargement it is

usual to record the approximate amount of the enlargement present by measuring it roughly in fingers' breadths below the costal margin. Children might be examined with advantage in villages at various points all along the various lines of communication in a district and also along the banks of the larger streams and the results indicated on a map. When the information detailed above has been obtained and the five sets of maps have been drawn up, it will be possible to correlate the data regarding malaria with that obtained by the survey of embankments, water-courses, spill areas and drainage. An indication will thus be obtained of the areas in which preventive work is most necessary.

### 63—Agricultural Survey.

101. The relationship that has been traced in the whole of this report between malaria and agriculture makes it essential that a survey of agricultural conditions both in malarious and non-malarious districts should be undertaken along with the investigations that have been suggested regarding embankments, inundation, drainage, sub-soil water level and malaria prevalence. The necessity for such a survey will, I think, be readily admitted. The lines such a survey should follow, must of course be left to the decision of the Agricultural Department. All that can be said here is that the correlations which have already been observed between agricultural conditions and malaria prevalence appear to show that generally speaking cultivable waste lands and current fallows are in excess where malaria is prevalent; that twice cropped areas are most frequent in non-malarious tracts; that as regards rice the cultivation of *Aus* paddy appears to be extending in certain of the more malarious areas; and that where jute is extensively cultivated malaria is less prevalent than where little of the fibre is produced. Certain other points also require elucidation. For example, the relative fertility of the soil in malarious as compared with non-malarious areas; the effect of embankments on crop production; and the influence of the height of the water-table on the yield of various crops. But as regards all these questions the Director of Agriculture is obviously the only person who can give adequate advice.

### 64—Publicity necessary.

102. The programme of work outlined in this chapter is designed for immediate application in those parts of the

province especially that as yet remain relatively free of malaria. If the progressive extension of malaria in these areas is to be checked it is essential that this programme should be carried out. It is certain that in the course of the various surveys that have been suggested as necessary facts will be brought to light showing the need for immediate action in clearing out silted-up channels and improving water communications generally. It is important that the objects and reasons for the respective surveys of embankments, water channels and spill areas should be widely published throughout every district where the work is being undertaken. And cultivators and other villagers should be encouraged to come forward and give information in respect to the various matters under investigation. The experience of intelligent cultivators is often very valuable, and their personal knowledge of what conditions in respect to inundation and drainage are harmful and what are beneficial will often be a valuable guide in carrying out the work. When the villagers once realise that the intention of Government is as far as possible to improve agriculture by conserving water-courses and improving drainage, there is little question that they will come forward with enthusiasm and loyally co-operate with district boards in forwarding the work.

## CHAPTER VII.

## The Amelioration of Malaria in the Deltaic Tracts of Bengal.

"*Malaria cannot be successfully combated merely by the distribution of quinine and the supply of mosquito nets.* The Government of a country devastated by the disease must conduct its campaign against the enemy under the generalship of the engineer and the agriculturist, rather than of the sanitary commissioner and the medical scientist. To the latter all credit is due and has in Italy been accorded for the discovery first made in that country of the true cause of malarial fevers*. But the expulsion of the pestiferous insect from the land requires the whole machinery of the State and the co-operation of the entire population to be brought into action."
—*Sir Edward Buck, K.C.S.I., L.L.D.*

### 65—The Nature of the Problem.

103. The earlier chapters of this report have shown that the prevalence of malaria in vast tracts of Western and Central Bengal and smaller areas in both Northern and Eastern Bengal is inextricably bound up with agricultural decline, impoverishment and depopulation. Malaria is a specific infectious disease that, under favourable conditions, can be eradicated by suitable measures aimed at destroying the parasite or the anopheles mosquitoes which transmit it. Physicians know that an acute malarial infection occurring in a person, who is favourably situated as regards food, clothing and housing and who can afford to adopt the proper measures, will usually yield to specific treatment very quickly. It is otherwise with the sufferer from chronic malaria, exposed for a long period to semi-starvation and adverse circumstances of all kinds. In his case specific treatment will fail to achieve its purpose, unless it can be combined with generous diet and other measures for improving his general health and relieving his miserable condition. What holds good with individuals holds good also in the case of communities. The amelioration of malaria in the progressive portions of Bengal, where agriculture is flourishing and prosperity increasing, is a relatively simple problem. In these favoured areas much may be hoped from specific anti-malarial sanitation, whether aimed at destroying the parasite with quinine or the anopheles mosquito; and the results of such measures may be expected to be directly proportionate to the expenditure incurred. But neither quinine nor anti-mosquito measures

*The discovery of the malaria parasite was made by Laveran in Algeria, and that of the mosquito cycle of the parasite by Ross in India

will restore declining agriculture. prevent the impoverishment of the people, or check depopulation, conditions that are characteristic of the decadent, malaria-stricken deltaic tracts in many parts of Bengal. In their case a much more fundamental remedy is required. And unless this remedy can be applied, there is little hope of reclaiming them from their present miserable condition.

104. Fortunately, a remedy is available ; a remedy which promises to relieve the country from economic stress and the Government from financial embarrassment ; a remedy that in the past has been adopted with complete success in many deltaic areas once threatened with absolute ruin by agricultural decline, impoverishment and depopulation. And this remedy can be applied in the case of Bengal also with the certainty of equal, if not greater, success. This remedy, moreover, will also eventually provide the resources required for applying the more specific measures of anti-malarial sanitation on a scale adequate for the control and final eradication of malaria. The great remedy referred to is Bonification. And the particular method of bonification peculiarly adapted for application to decadent delta tracts is Irrigation. The whole question of bonification is so important that an entire chapter will be devoted to its discussion ; meanwhile, the specific measures of anti-malarial sanitation must be considered in detail. Financial considerations at the moment stand in the way, so that these measures cannot be applied at present on a scale commensurate with the evil they are designed to remedy ; never-the-less they must be given their place in the plan of campaign ; and, when economic conditions have been restored by irrigation, it is to these measures that we must eventually look for the final triumph over malaria. Specific anti-malarial sanitation is in the nature of a direct offensive. A direct offensive against a strongly entrenched enemy is extremely costly and may fail, unless pushed home with the greatest vigour regardless of expense. A skilful general whose immediate resources are limited, instead therefore of courting failure and loss by attempting a frontal attack that must end in failure, strives to keep the enemy at bay while seeking to make their position untenable by a threat to their flank or rear or a bold stroke at their communications. But let the enemy once relax his hold and our good general will drive home his attack all along the line. The same course must be followed in the campaign against malaria. Malaria, the arch enemy of Bengal, is at present so strongly entrenched in many parts of the country as to defy direct attack

on any scale now possible with the meagre resources at our disposal. But malaria can be forced to evacuate its strong position by a flank attack directed upon its main allies, agricultural decline, economic stress and depopulation. This flank attack must take the form of irrigation ; and as the methods of irrigation specially adapted for application in the delta tracts of Bengal will also reduce the number of dangerous anopheles mosquitoes very greatly, irrigation will thus strike a simultaneous blow at the transport or line of communications of the malaria parasite. When, as the result of irrigation, agricultural prosperity is restored, the food supply of the people increased. depopulation checked and Anophelines simultaneously reduced in number, malaria will suffer its first defeat and gradually begin to retire. Every possible measure of direct attack must then be concentrated upon it with the object of hastening its final discomfiture and driving it completely out of the country.

### 66—Direct Attacks upon Malaria.

105. Direct attacks can be made against malaria by the following measures :—

(1) medical treatment aimed at destroying the malarial parasite by the use of quinine ;

(2) anti-mosquito measures specially directed against anopheles mosquitoes and including—

(*a*) measures for destroying the adult insect ;

(*b*) measures for destroying the larvæ (*i*) by the treatment of collections of water with larvicides. (*ii*) by the introduction of small fish and other natural enemies ;

(*c*) measures for the more effective permanent obliteration of breeding places either (*i*) by draining them, (*ii*) by filling them up ;

(*d*) measures for the temporary obliteration of the more dangerous small collections of water by "covering" them with an excess of water during the wet season (which is the dangerous period of the year.) and thus preventing a large increase of anopheles and spread of malaria that would otherwise occur.

(3) Measures of protection aimed at preventing anopheles from biting human beings by the use of mosquito nets, protective clothing and medicaments which tend to repel adult mosquitoes, and the application to the windows and doors of dwellings of wire-gauze screens.

### 67—Combating Malaria by Quinine: the Italian System.

106. Experience has shown that malaria can be greatly diminished by the widespread use of quinine. In many countries therefore attempts have been made to encourage the use of quinine by making it easily available to the population at a relatively low price. This method has *been already used to some extent* in India; but it has been much better organised in Italy and Greece. Similar measures have been adopted in Portugal, Austria, Russia, Algeria, Corsica, Bulgaria and Argentina. In most of these countries, the measures adopted by the Government for the popularisation of quinine have been greatly assisted by voluntary philanthropic associations, such as the Anti-Malarial League of Greece and the Italian Red Cross Society. Following the earlier example of Bengal, the Italian Government at first aimed at providing a supply of quinine throughout the country and making it available to all classes of the community at a fixed price. They did not, however, make it a State monopoly or interfere in any way with its supply by private wholesale and retail agencies. The price, while fixed sufficiently low to bring it within the reach of most of the population, was not so low as to prevent chemists and druggists deriving a small profit from the sale of the drug. In order to avoid the charge that they were taxing the infirmities of the people to increase revenue, the Italian Government established the principle that all profits accruing from the sale of State quinine should be devoted to anti-malarial work. The statement below gives the amounts of State quinine sold in Italy during a number of years :—

**Statement showing the Sales of State Quinine in Italy.**

| Year | State quinine sold | Profit * |
|---|---|---|
| | lbs. | Rs. |
| 1902-03 ... | ... 4,932 | 21,250 |
| 1903-04 ... | ... 15,914 | 1,14,400 |
| 1904-05 ... | ... 30,956 | 1,14,600 |
| 1905-06 ... | ... 41,166 | 1,85,000 |
| 1906-07 ... | ... 45,590 | 2,88,000 |
| 1907-08 ... | ... 53,572 | 4,37,539 |
| 1908-09 ... | ... 51,997 | 4,81,130 |
| 1909-10 ... | ... 47,643 | 4,50,000 |
| 1910-11 ... | ... 50,149 | 5,27,070 |

* The figures quoted show the approximate profit to the Italian Government which is ear-marked for expenditure on grants for anti-malarial work

107. In organizing the sale of State quinine, the Italian Government have proceeded on strictly business lines. They fixed a retail price, which allowed for a reasonable profit, although much lower than that previously charged by the druggists; and so while safeguarding the interests of the public, they did not enter into unfair competition with honest traders. At the same time, as already mentioned, all profits derived from the sale of this State quinine were expressly ear-marked for the purpose of making grants to local bodies for anti-malarial work. An educational campaign and widespread advertising formed a prominent feature of the Italian system, under which there has been a wonderful expansion in the sale of all preparations of quinine, whether supplied by the State or from private sources, and a corresponding reduction in the prevalence of malaria. In 1887, 15 years before the introduction of State quinine, the deaths from malaria in Italy were 21,000. Since the consumption of quinine became general they have fallen below 3,000. The annual consumption of quinine prior to the introduction of State quinine in 1902, was about 30,000 to 33,000 lbs.; since 1905 it has been more than double this and has steadily increased.

108. In addition to the preparations of State quinine, which are on sale throughout Italy by licensed vendors, druggists in that country annually dispose of nearly 30,000 lbs. of the drug derived from other sources. The population of Italy in 1909 was just under 34,000,000, and the annual consumption of quinine in 1910 amounted to very nearly 16 grains per head of the population. Compare this with the total consumption of quinine in India, which in 1910 amounted to 160,000 lbs. only, about double that of Italy, whereas the Indian popalation is nine times as great and many parts of the country far more malarious. The Italian Government have to purchase their supplies of quinine in the open market, but the preparations of "State quinine" (which include two kinds of sugar-coated tablets, special phials of solution for sub-cutaneous injection and bon-bons of tannate of quinine for children) are manufactured at a special State factory. The tablets which contain 3⅓rd grains of quinine are issued in tubes of 10. The retail price of a tube of 10 tablets of quinine bi-sulphate is equal to about 3½ *annas*, which is practically the equivalent of the price of *annas* 8 formerly charged in Bengal for 20 four-grain tablets of Government quinine.

### 68—Quinine Legislation in Italy.

109. The Italians have not been content with providing merely for the supply of pure State quinine at a moderate price but have passed numerous laws to regulate its distribution. The first of these laws was passed in December 1900 and empowered the Government to manufacture and provide State quinine on sale to the public at a minimum price. A second Act was passed on the 2nd November 1901 which laid down the right of workers of every kind to have gratuitously the State quinine for the treatment of fever from the doctors employed by the local authorities (communes) at the expense of the respective employers. A third Act was passed on the 22nd of June 1902. empowering Government to supply State quinine at a concession rate to local authorities and charitable institutions and to persons who desired or were obliged to distribute it gratuitously to the workers. A fourth Act was passed on the 25th of February 1903, establishing the right of the poor to have quinine and other necessary drugs given them gratuitously by the local authorities or charitable institutions. Finally, a fifth Act was passed on May 19th, 1904, establishing the further right of workers of every kind to have quinine, not only for the treatment of acute malaria, but also for purposes of prophylaxis. The Italian anti-malarial legislation has not only been imitated by Austria and by France for Corsica and Algiers. but has also been wholly adopted by Portugal. Bulgaria, Argentina and Greece.

### 69—The Sale of Quinine in Greece.

110. The quinine policy of Italy has been imitated by the Greek Government. On the 15th of December 1907. the Greek Chamber passed a law similar to the original Italian Quinine Act, under which the Government acquired the right to purchase and to sell any of the salts of quinine recommended by the Royal Sanitary Council. State quinine is now on sale in Greece by all public treasuries, post and telegraph offices, educational functionaries and by such other authorities as may be chosen under the Royal Decree. It is also sold retail to the public by chemists, grocers and other merchants, who derive a small profit therefrom. The importation and sale of quinine, other than the State quinine, is made liable to examination and is not permitted to be sold unless its quality is equal or

superior to that of the State quinine. Heavy penalties are prescribed for persons selling State quinine or the commercial articles at prices above that fixed by law, or selling adulterated quinine, smuggling quinine into the country or selling it underweight. The law also obliges the local authorities of all areas severely scourged by malaria to enter in their budget each year the amount destined for the purchase of State quinine to be distributed gratis to the poor. Greece is very severely scourged by malaria. It is estimated that, out of a total population before the war of 2,631,952, an average of 770,000 or 29 per cent. are every year attacked by malaria, and in some years the proportion of cases is heavier. Thus, in 1905, it was supposed that more than half the population were attacked and over 6,000 died of the disease. In 135 communes, out of a total of 445, over 40 per cent. of persons were attacked; in 59 communes the percentage was 41 to 50; in 33 it was 51 to 60; in 23 it was 61 to 70, and in another 20 communes it ranged from 70 to 90 per cent. Only 29 communes were entirely free of malaria. Prior to the passing of the Greek Quinine Act, the average amount of quinine consumed in the country was about 13,200 lbs. per annum. But the first year the Act was in force, the State quinine sold to the public alone amounted to nearly 24,000 lbs., or an average of 64 grains per head of the population. A further amount of the drug derived from other sources was also disposed of by private vendors. The total consumption of quinine is thus very considerable and in proportion greatly exceeds that consumed in Italy. Unfortunately, figures are not available to show what effect the increased comsumption of quinine has had upon malaria.

### 70—The Sale of Quinine in Bengal.

111. In Bengal the sale of Government quinine to the general public through the agency of post-offices was commenced in 1892, a packet of 5 grains in powder being retailed at a *pice*. But when it was pointed out in 1904 that a 5-grain dose of quinine was inadequate for the treatment of malaria the amount of quinine in each pice-packet was increased to seven grains. In 1909 a further change was made, 10 grains of powdered quinine or three 3⅓rd grain tablets being supplied for a *pice*. In 1913, the sale of tubes of quinine tablets, first begun in Eastern Bengal in 1909, was introduced throughout Bengal, the retail price of each tube of twenty-four-grain tablets

being fixed at three *annas* a tube. The price was subsequently raised to four *annas* per tube, at which it remained until recently. In May 1918, the retail price was doubled in order to check the large amount of profiteering that was going on owing to the abnormally high price of quinine in the open market.

112. The statement below gives details of the issues of quinine to Civil Surgeons from 1911 until May 1918 for supply to the public through post-offices and other retail vendors. In December 1918 a Central Depôt was established to supply post-offices direct. Orders were issued in May of that year also to the effect that a single tube only was to be sold at one time to each individual purchaser. This was done to prevent the fraudulent purchase of large amounts by persons who merely wished to retail it again at an enhanced profit.

**Sale of Quinine through Bengal Post-offices.**

| Years. | Amount. | Description. | Remarks. |
|---|---|---|---|
| | lbs. | | |
| 1911 | 3,313 | Price packets | |
| 1912 | 3,177 | ditto | 1,604 lbs. and 3¼rd grain tablets 1,573 lbs. |
| 1913 | 7,636 | ditto | 849 lbs. 3¼rd grain tablets 1,363 lbs. and "treatments" 5,424 lbs. |
| 1914 | 12,225 | Tubes of tablets or "treatments" only | The sales shown in 1914 and onwards till about 1917 were swollen by purchases by District Boards of tubes of "treatments" for use at dispensaries, as the result of an order by the Medical Department. Later on many tablets were purchased in bulk and consequently were not included in the figures relating to post-office sales. |
| 1915 | 13,152 | ditto. | |
| 1916 | 11,038 | ditto | |
| 1917 | 11,389 | ditto. | |
| 1918 | 7,096 | ditto. | |
| 1919 | 7,438 | ditto. | |
| 1920 | 8,902 | ditto. | |

113. At the present time, quinine is on sale through 3,225 post-offices distributed more or less evenly throughout the province. The number of pounds of quinine sold through the post-offices in each of the natural divisions during 1919-20 is given below, together with the average amount it represents per head of the respective populations. The amount of quinine which should be sold in each division on

the basis of Italian and Greek consumption, respectively, is added for purposes of comparison :—

**Sales of Quinine in each Natural Division.**

| | Quinine sold, 1919. | Grains per head of population. | Quinine sold, 1920. | Grains per head of population. | Quinine required on Italian scale. | Quinine required on Greek scale. |
|---|---|---|---|---|---|---|
| | lbs. | | lbs. | | lbs. | lbs. |
| Western Bengal ... | 1,368 | 1·12 | 1,227 | 1·11 | 20 000 | 80,000 |
| Central ,, ... | 1,417 | 1·16 | 1,741 | 1 42 | 20 000 | 80,000 |
| Northern ,, ... | 924 | 0 63 | 1,0 9 | 0·69 | 23,000 | 92,000 |
| Eastern ,, ... | 3.729 | 1·51 | 4.924 | 1·99 | 40,000 | 160,000 |

114. It will be seen from the figures cited above that the amount of quinine sold is ridiculously small when compared with what it would be on the basis of a reasonable rate of consumption. It may be noted also that the sales are greatest in the less malarious division of Eastern Bengal. As a matter of fact the highest district sales in each of the past two years, viz., 903 and 955 lbs., respectively, have occurred in Tippera. This is probably the least malarious of all the Eastern Bengal districts, and yet it purchases through the post-offices as much quinine as the whole of Northern Bengal.

### 71—Lack of Business Principles.

115. Business principles have never guided the sale of Government quinine to the public in Bengal. The idea has been that quinine should, if necessary, be sold at a loss with a view to bringing it within reach of the poor. Yet no serious attempt has ever been made to educate the people in regard to the value of the drug as a remedy for malaria. It has been assumed that if quinine is cheap, ignorant villagers will somehow or other learn its value and make use of it. But enquiry shows that the very poor rarely or never purchase Government quinine. In 1911, as the result of 600 personal enquiries among villagers in a malarious part of the Dacca district, only five persons were discovered who had themselves purchased quinine or knew of others who had done so. On the other hand, it was found that the principal purchasers were Government officers and other educated persons who already knew the value of quinine and could afford to purchase it at the ordinary market rates.

116. Formerly a very large proportion of the Government quinine also used to find its way into the hands of persons who purchased it with the view of re-selling it again in some other form at a profit. In every town and large village throughout Bengal, there are persons who make a living by preparing and selling remedies for enlarged spleen and malarial fever. Many of these nostrums contain quinine, disguised by colouring and flavouring matters; and the labels on the bottles frequently recommend the medicine as a remedy for "Quinine Atkan Jor" (a fever supposed to result from the taking of quinine). The makers of these quack medicines know that Government quinine is pure, and, when it could be purchased below the market rate, they naturally preferred it to any other brand. In this connection, the history of the sale of quinine in Bakarganj is most significant. Up to 1909, the quinine sold in Bakarganj exceeded that sold in all the other districts in the province put together. Persons would often visit the Civil Surgeon's office, pay Rs. 200 at one time for pice-packets. Bakarganj is not malarious, but it was assumed that the villagers were learning to appreciate the value of quinine. In 1909, however, pice-powders were suddenly replaced by tablets and immediately the sales of quinine in Bakarganj district decreased, falling almost to the lowest in the province. This is to be accounted for by the fact that most of the sales of quinine that used formerly to take place in Bakarganj were not to legitimate purchasers, but to persons who wished to make use of its cheapness for their own ends. These people found the tablet form unsuitable for their purpose and so ceased to buy and hence the reduced sales. The facts stated above are sufficient to condemn the system of selling quinine below actual cost. But there are other serious objections to such a practice, the chief one being the utter impossibility of preventing profiteering under such a system. As an example of what took place quite recently in Bengal, before the price of "treatments" was doubled, it may be mentioned that, an authorised vendor who sold 17 packets in 1917 disposed of nearly 700 in 1918; on enquiry it was found that he was the proprietor of a malaria specific. There are very grave dangers attaching to the system of selling quinine below the market price. It is impossible under such a system to provide safeguards against abuse, and those who chiefly benefit are not the poor and ignorant but the educated and well-to-do.

### 72—Some Financial Aspects of the Quinine Question.

117. It is instructive to glance at the figures quoted in the statement below, which show the price per pound paid by the public for Government quinine, the commission per pound of quinine sold drawn by retail agents and the net amount actually received by Government per pound of quinine sold and the approximate cost of bottles and packing, etc. :—

| Years. | Cost of Government quinine to the public per pound. | Commission obtained by retail agents per pound. | Net price received by Government per pound. | Cost of tubes, packing, etc., to Government per pound. |
|---|---|---|---|---|
| | Rs. A. P. | Rs. A. P. | Rs. A. P. | Rs. A. P. |
| 1892-1903 ... | 21 14 0 | 3 8 0 | 18 6 0 | ... |
| 1904-1909 ... | 15 10 0 | 2 8 0 | 13 2 0 | ... |
| 1909 1912 ... | 10 15 0 | 1 12 0 | 9 3 0 | ... |
| 1913 ... | 16 6 6 | 3 6 3 | 6 5 6 | 10 1 6 |
| 1914-1918 ... | 21 14 0 | 3 6 3 | 11 12 6 | 10 1 6 |
| 1918 1919 ... | 43 12 0 | 5 7 6 | 19 2 6 | 19 2 6* |

* The Jail Department makes a profit of about a lakh of rupees per annum on this cost.

118. The amount received by Government per pound of quinine in recent years may next be compared with the wholesale market price of the drug per pound in Calcutta.

| Years. | Market price of quinine. | Net price received for Government quinine. | Approximate loss to Government on market value of quinine sold. |
|---|---|---|---|
| | Rs. A P. | Rs. A. P. | Rs. A. P. |
| 1912 ... | 9 0 0 a lb. | 9 3 0 | Not available. |
| 1913 ... | 12 8 0 ,, ,, | 6 5 6 | 47,015 4 6 |
| 1914 ... | 14 0 0 ,, ,, | 11 12 6 | 27,122 15 6 |
| 1915 ... | 15 8 0 ,, ,, | 11 12 6 | 48,909 0 0 |
| 1916 ... | 34 0 0 ,, ,, | 11 12 6 | 2,45,250 7 0 |
| 1917 ... | 32 0 0 ,, ,, | 11 12 6 | 2,27,271 5 6 |
| 1918 ... | 50 0 0 ,, ,, | 19 2 6 | 2,18,867 4 0 |
| 1919 ... | 33 0 0 ,, ,, | 19 2 6 | 1,24,676 13 0 |

119. Among the figures cited in the above table, attention should be specially directed to those which relate to the loss occasioned to Government by the sale of quinine at prices below the market rates. It must be explained that the sums quoted are estimates of the loss that could have

occurred if Government had been obliged to purchase in the open market quinine they sold to the public. But as a matter of fact Government have purchased very little quinine in the market and have depended almost entirely upon the supplies of quinine manufactured at their own factory. But this has only been possible because of the relatively scanty consumption of the drug. The maximum capacity of the factory is about 50,000 lbs. of quinine per annum, and in order to produce this amount about 1,000,000 lbs. of locally grown bark would be required. The Government cinchona plantation possesses cinchona trees capable of eventually yielding a total of about 150,000 lbs. of quinine, and there is little or no land suitable for extension. The bark on the trees together with a small manufactured reserve of quinine is now practically the only existing barrier against a monopoly of Java quinine. The world's consumption of quinine in 1910 was about 1,065,000 lbs. derived almost wholly from Java, and of this India took nearly one-sixth. Cinchona trees require at least nine years' growth before they can afford a supply of bark suitable for the manufacture of quinine, so that there can be no alternative source of quinine supply for the next ten years.

120. Clearly, these facts have to be taken into account when discussing the future policy in respect of quinine distribution. Unless an adequate supply of quinine at a reasonable cost can be assured, whatever system is adopted may at any time be threatened with a break down. Consideration of the facts mentioned will show that the question both of the immediate and ultimate source of supply must be decided before it is possible to embark on a serious campaign for extending the sale of quinine, otherwise Government might suddenly find itself faced, on the one hand, with a depletion of its available stocks and, on the other, with a world monopoly which, in the face of the increased demand, would probably result in a great enhancement of the price. The price might easily rise to double or treble the present figure, which is now five or six times what it was 10 or 12 years ago.

### 73—The Supply of Quinine.

121. With the exception of Madras, Bengal is the only province where there has been any serious attempt to maintain a stock of quinine sufficient to meet the local

demands. Not only has Bengal manufactured her own quinine, but she has bought larger amounts than any other province. It is probable that, provided she can procure cinchona bark for manufacturing purposes, she could allow for a great local expansion in the use of the drug. Last year the sale of quinine through post-masters nearly reached 9,000 lbs., and it is possible the total consumption of Government quinine in the province including that given gratuitously and that purchased direct by dispensaries, etc., may have been about 17,000 lbs. If the Bengal Government had to consider only their own wants they could, with the present manufacturing facilities, meet a demand three times as great as the present one, provided only that cinchona bark can be made available. The bark on the trees at the cinchona plantations is limited, equalling about 150,000 lbs. of quinine. But by purchasing bark, Bengal can always manufacture quinine at a cost much below that of the current wholesale price of the drug, viz., under Rs. 10 per lb. as against Rs. 40 to Rs. 50. It would cost, for example, at present rates Rs. 20 to Rs. 25 lakhs to purchase 50,000 lbs. of quinine which could be manufactured if bark is available at a reasonable price for less than Rs. 5 lakhs.

### 74—Gratuitous Distribution of Quinine.

122. Turning to the question of gratuitous distribution of quinine, it must be pointed out that the charitable dispensaries throughout the province provide an agency through which a considerable amount of quinine is every year distributed to the necessitous poor. Reference to the annual reports on the working of hospitals and dispensaries shows that a very large number of patients receive treatment for malaria at these institutions. The total number of admissions for malaria reported each year since 1914 is as follows :—

| Years. | Admissions for malaria. | Years. | Admissions for malaria. |
|---|---|---|---|
| 1914 ... | 1,408,127 | 1919 ... | 2,005,453 |
| 1915 ... | 1,720,665 | 1920 ... | 2,314,584 |
| 1916 ... | 1,451,535 | 1921 ... | 2,387,543 |
| 1917 ... | 1,657,912 | 1922 ... | 2,030,919 |
| 1918 ... | 1,910,200 | 1923 ... | 2,135,934 |

123. Unfortunately, it is not possible to discover the actual amount of quinine distributed among these patients each year, but by comparing the number of malaria cases admitted to State, public, local fund and private aided dispensaries with the expenditure on European medicines at these institutions we can get some idea as to whether the amount of quinine provided each year is adequate or not :—

| Years. | Total admissions for malaria at State, public, local fund and private aided dispensaries. | Total expenditure on European medicines. |
|---|---|---|
| | | Rs. |
| 1914 ... | 1,053,413 | 3,17,306 |
| 1915 ... | 1,333,000 | 3,54,638 |
| 1916 ... | 1,146,092 | 4,04,256 |
| 1917 ... | 1,277,627 | 4,18,533 |
| 1918 ... | 1,515,451 | 4,81,788 |
| 1919 ... | 1,622,806 | 4,63,161 |
| 1920 ... | 1,901,386 | 5,68,554 |
| 1921 ... | 1,931,085 | 6,02,194 |
| 1922 ... | 1,691,171 | 5,68,178 |
| 1923 ... | 1,751,363 | 5,07,404 |

124. The amount of quinine obtainable for the whole expenditure disbursed under the head of European medicines would have been as follows :—

| Years. | At current market rates | Government quinine. |
|---|---|---|
| | lbs. | lbs. |
| 1914 ... | 22,664 | 14,423 |
| 1915 ... | 22,879 | 16,119 |
| 1916 ... | 11,889 | 18,375 |
| 1917 ... | 13,079 | 19,024 |
| 1918 ... | 9,635 | 21,899 |
| 1919 ... | 14,035 | 19,298 |
| 1920 ... | 11,371 | 17,229 |
| 1921 ... | 10,036 | 12,545 |
| 1922 ... | 12,626 | 15,782 |
| 1923 ... | 16,913 | 18,792 |

125. The total amount of quinine required for the treatment of the cases of malaria admitted to the abovementioned institutions, at the moderate estimate of only 80 grains a case, would have been as follows :—

| Years. | Amount of quinine required at 80 grains a head. | Cost of this amount of Government quinine. | Percentage of total expenditure on European medicines. | Cost of this amount of quinine at current market rates | Percentage of total expenditure on European medicines. |
|---|---|---|---|---|---|
| | lbs. | Rs. | Per cent. | Rs. | Per cent |
| 1914 ... | 12,132 | 2,64,704 | 83 | 1,68,448 | 53 |
| 1915 ... | 15,232 | 3,35,104 | 94 | 2,36,096 | 66 |
| 1916 ... | 13,096 | 2 88,112 | 71 | 4,45,264 | 110 |
| 1917 ... | 14,600 | 3,21,200 | 76 | 7,30,000 | 174 |
| 1918 ... | 17,320 | 3,81,040 | 79 | 5 71,560 | 118 |
| 1919 ... | 18 546 | 4,15,104 | 96 | 6,12 018 | 132 |
| 1920 ... | 21,731 | 7,17,123 | 126 | 10,86,550 | 191 |
| 1921 ... | 22,755 | 19,92 240 | 181 | 13,65,300 | 226 |
| 1922 ... | 19 327 | 6,95,772 | 122 | 8.69,715 | 153 |
| 1923 ... | 20,015 | 5,40 405 | 106 | 6,00,450 | 118 |

126. The figures given in the above table show that the quinine treatment administered to sufferers from malaria attending the dispensaries referred to cannot possibly be adequate. There is unfortunately no accurate record of the actual amount of quinine consumed in the dispensaries, but certain incomplete returns received from municipalities and district boards relating to the amounts of quinine purchased by them during 1915 to 1924 suggest that it is ordinarily little more than 25 per cent. of that required to provide 80 grains of the drug for each new case of malaria admitted for treatment. In other words, it is probable that the amount of quinine available is only enough to allow each case on the average about 20 grains, or just sufficient for one day's treatment. Information formerly received shows that quinine was actually administered in certain areas in doses of only about one grain.

127. The table below gives fever cases admitted as out-patients during 1923 in each of the natural divisions together with an approximate estimate, largely based on

actual returns from most districts, of the total amounts spent by district boards on quinine, exclusive of Government grants for this purpose :—

| Divisions. | Malaria cases, 1923. | Mean fever index, 1923. | Expenditure on quinine in 1923. | Average of 3 years' expenditure. |
|---|---|---|---|---|
| | | Per cent. | Rs. | Rs |
| Western Bengal ... ... | 375,426 | 47·6 | 22,551 | 22,991 |
| Central ,, ... ... | 372,964 | 36 7 | 22,436 | 24,462 |
| Northern ,, ... ... | 448,361 | 55·7 | 25,195 | 28,293 |
| Eastern ,, ... ... | 373,031 | 17 0 | 24,522 | 23,555 |

### 75—Free Grants of Quinine by Government.

128. During the last few years, instead of distributing quinine as was done formerly by means of a special itinerant staff, Government have adopted the policy of making free grants of the drug to District Boards, Municipalities and certain other agencies, *e.g.*, mission dispensaries. The amounts so granted during the past three years have been as follows :—

| Years. | Rs. | Years. | Rs. |
|---|---|---|---|
| 1918-19 ... | 50,000 | 1922-23 ... | 42,000 |
| 1919-20 ... | 46,000 | 1923-24 ... | 64,000 |
| 1920-21 ... | 72,680 | 1924-25 ... | 1,20,000 |
| 1921-22 ... | 70,000 | 1925-26 ... | 1,20,000 |

129. The amounts spent by local authorities, including both District Boards and Municipalities, on purchasing quinine and cinchona febrifuge, in addition to that received from Government, has been approximately as follows, in each of the last six years :—

| Natural divisions. | 1918-19. | 1919-20 | 1920-21. | 1921-22. | 1922-23. | 1923-24. |
|---|---|---|---|---|---|---|
| | Rs. | Rs. | Rs. | Rs. | Rs. | Rs. |
| Western Bengal ... | 32,963 | 25,828 | 38,790 | 42,182 | 32,607 | 38,495 |
| Central ,, ... | 28,553 | 22,014 | 38,211 | 44,561 | 38,259 | 38,304 |
| Northern ,, ... | 28,612 | 20,287 | 28,074 | 45,475 | 42,007 | 41,227 |
| Eastern ,, ... | 13,982 | 16,606 | 20,808 | 33,248 | 33,107 | 36,566 |
| Total ... | 1,04,010 | 84,745 | 1,25,883 | 1,63,466 | 1,45,980 | 1,54,592 |

It would appear from these figures that the sums actually allotted for quinine and cinchona derivatives, including that given by Government are, always less than Rs. 2 lakhs per annum and ordinarily amount to about 1½ lakhs. Obviously. the treatment of malaria cases must be, in these circumstances, hopelessly inadequate.

### 76—Itinerant Quinine Distribution a Failure in Rural Areas.

130. Some years ago, 24 Sub-Assistant Surgeons were employed during the malarious season in distributing quinine gratuitously to sufferers from malaria in the Presidency Division and other localities. Similar work was also undertaken in certain of the Eastern Bengal districts, 14 Sub-Assistant Surgeons and three Assistant Surgeons being employed for this purpose in the Keraniganj thana of the Dacca district in 1911, and five Sub-Assistant Surgeons under an Assistant Surgeon working on similar lines in the Jalpaiguri, Rajshahi and Malda districts during succeeding years. But the method of distributing quinine by an itinerant agency of this kind proved a failure. A comparison of the amount of quinine actually distributed with that of the cost of the distributing agency showed that every four annas worth of quinine, distributed in this way, cost Government on the average a sum of Re. 1 to Re. 1-4 on the staff employed.

### 77—Quinine Distribution a Success in Dinajpur Town.

131. At Dinajpur town, the distribution of quinine to children and others suffering from chronic malaria and enlarged spleen was carried out for a period of between three and four years. The amount of quinine used each year was about 150 or 160 lbs., which is equal to about 70 grains per head of the total population of the town. The preparations of quinine used cost about Rs. 18 per lb. The average cost of distribution, which included small monthly salaries to a number of lay distributors, as well as the pay both of an Assistant Surgeon and a Sub-Assistant Surgeon, was about exactly equal to the value of the quinine used. The measure had a considerable effect in reducing the prevalence of sickness. Dinajpur town is moderately malarious when compared with many parts of Bengal. The spleen index was nearly 30 per cent., and the local fever index was also about 30 per cent. at the beginning of the experiment. During the following three

years both the spleen index and the prevalence of fever was reduced and local medical men complained of being "somewhat idle." To administer quinine throughout the province at the rate allowed in Dinajpur would entail an annual consumption of about 450,000 lbs. of the drug. or very nearly half the world's present supply of quinine; and the cost at present market prices would be about 1½ crores of rupees. If the price of quinine advanced, as it undoubtedly would if used on this scale, the cost would be increased proportionately.

### 78—Fever Cases attending Dispensaries in 1920.

132. During 1920, the admissions for malaria at 561, out of a total of about 700. dispensaries in the province numbered 1,811.739, distributed as follows :—

| Natural divisions. | Number of dispensaries. | Number of malaria cases. | Fever index. | Population of division 1911. |
|---|---|---|---|---|
| Western Bengal ... | 108 | 501,811 | 55 per cent. | 8,467,314 |
| Central ,, ... | 98 | 539,491 | 45 ,, | 9,445.321 |
| Northern ,, ... | 149 | 435.870 | 30 ,, | 10,138,302 |
| Eastern ,, ... | 206 | 334,567 | 12 ,, | 17,432,140 |

Compared with figures obtained in a somewhat similar manner in 1912 and 1917. there appears to have been a great increase of malaria in the last four years. In Eastern Bengal, the fever index is now much higher than in 1912. As the people in Eastern Bengal are generally speaking much better off than those in Western and Central Bengal, they can afford to purchase quinine. hence the larger sales in the former division. The largest number of malaria cases attending individual dispensaries is met with in Central Bengal with an average of 5.505 new admissions per annum ; Western Bengal comes second with 4,646 ; Northern Bengal third with 2,925 ; and Eastern Bengal last with 1,648.

133. The two tables below are specially instructive as indicating both the distribution of malaria in the province and the corresponding variation in the needed supply of quinine :—

**Fever indices at dispensaries in each natural division.**

| Fever index or percentage of fever cases to total admissions. | Western Bengal number of dispensaries returning fever indices as in first column. | Central Bengal number of dispensaries returning fever indices as in first column. | Northern Bengal number of dispensaries returning fever indices as in first column. | Eastern Bengal number of dispensaries returning fever indices as in first column. |
|---|---|---|---|---|
| Under 10 per cent. | 4 | 0 | 3 | 66 |
| From 10 to 20 ,, | 5 | 3 | 20 | 71 |
| ,, 20 to 30 ,, | 7 | 14 | 19 | 37 |
| ,, 30 to 40 ,, | 15 | 18 | 55 | 15 |
| ,, 40 to 50 ,, | 10 | 22 | 36 | 14 |
| ,, 50 to 60 ,, | 16 | 21 | 13 | 3 |
| ,, 60 to 70 ,, | 24 | 13 | 3 | 0 |
| ,, 70 to 80 ,, | 19 | 7 | 0 | 0 |
| ,, 80 to 90 ,, | 7 | 0 | 0 | 0 |
| Over 90 ,, | 1 | 0 | 0 | 0 |

**Percentage of dispensaries under each class of fever index.**

| Fever index or percentage of fever cases to total admissions. | Western Bengal. | Central Bengal. | Northern Bengal. | Eastern Bengal. |
|---|---|---|---|---|
| Under 10 per cent. ... | 3·7 | 0·0 | 2·0 | 32·0 |
| From 10 to 20 ,, ... | 4·6 | 3·0 | 13·4 | 34·4 |
| ,, 20 to 30 ,, ... | 6·4 | 14·2 | 12·7 | 17·9 |
| ,, 30 to 40 ,, ... | 13·8 | 18·3 | 36·9 | 7·2 |
| ,, 40 to 50 ,, ... | 10·1 | 22·4 | 14·1 | 6·7 |
| ,, 50 to 60 ,, ... | 14·8 | 21·4 | 8·7 | 1·4 |
| ,, 60 to 70 ,, ... | 23·1 | 13·2 | 2·0 | 0·0 |
| ,, 70 to 80 ,, ... | 18·5 | 7·1 | 0·0 | 0·0 |
| ,, 80 to 90 ,, ... | 6·4 | 0·0 | 0·0 | 0·0 |
| Over 90 ,, ... | 0·9 | 0·0 | 0·0 | 0·0 |

### 79—The Inadequate Consumption of Quinine.

134. The facts that have been stated show that pending the adoption of other measures there is no hope of eradicating malaria from Bengal solely by quinine. The cost would be too great even if the necessary amount of the drug was available, and if we could use the whole world's supply it is doubtful if it would be sufficient for the purpose. We have seen that in Greece the consumption of quinine has already reached an average of over 60 grains per head of the population and that in less malarious Italy the average consumption has long been 16 grains per head. Bengal would require at the latter rate 103,000 lbs. of quinine per annum and at the former no less than the tremendous total of 412,000 lbs. per annum or 40 per cent. of the world's supply. The price of quinine is about Rs. 28 per lb., and it is doubtful if any considerable quantity could be purchased at less than Rs. 30 per lb. At this rate quinine on the Italian scale would cost Rs. 30,00,000 per annum and on the Greek scale Rs. 1,23,60,000 per annum The Bengal Cinchona Plantation possesses at the highest estimate only 150,000 lbs. of available quinine, in the bark on the trees, as yet unmanufactured; the quinine factory when working at its maximum output can turn out 50,000 lbs. of quinine per annum. Meanwhile, nearly 2,000,000 malaria cases attend at dispensaries and receive totally inadequate treatment, and something under 10,000 lbs. of quinine or little more than 1 grain per head of the population is sold to the public through post-offices. Of course considerable quantities of quinine are supplied by private vendors, and large amounts are distributed by employers to tea garden coolies in the Darjeeling and Jalpaiguri districts. But taking everything into consideration, the quinine actually consumed is wholly insignificant when compared with the vast quantity really needed to effect a diminution of malaria in the province as a whole.

### 80—The Infected Population.

135. The population infected with malaria is enormous. At the 1911 census, the total population of the province was 45,483,077, distributed as follows :—

| | | | |
|---|---|---|---|
| Western Bengal | ... | ... | 8,467,314 |
| Central „ | ... | ... | 9,445,321 |
| Northern „ | ... | ... | 10,138,302 |
| Eastern „ | ... | ... | 17,432,140 |

At a rough estimate some thirty millions of these people are infected with malaria and more than ten millions suffer from the disease in an aggravated form. The distribution of mild and severe malaria is probably somewhat as follows :—

| | Malarial infections. | Severe malaria. |
|---|---|---|
| Western Bengal ... | 8,000,000 | 5,250,000 |
| Central ,, ... | 8,500,000 | 3,550,000 |
| Northern ,, ... | 8,500,000 | 1,050,000 |
| Eastern ,, ... | 5,000,000 | 500,000 |
| Total ... | 30,000,000 | 10,350,000 |

136. There has been a great extension of malaria in several of the districts of Eastern Bengal in recent years since the construction of several hundred miles of railway, and the great districts of Dacca and Mymensingh especially show signs of being far more seriously affected than formerly. Tangail, Manikganj and the north of Faridpur district are the areas of Eastern Bengal most seriously affected with malaria, but the main increase appears to be occurring in tracts that up to a few years ago were but little affected with the disease. The estimate of total malaria infections is by no means a high one. There are relatively few areas at present in which the majority of the population does not suffer from an attack of malaria at least once in the year. But in the unhealthy districts a vast proportion of the population is composed of chronic sufferers from the disease who are a prey to recurring attacks of fever for many months every season.

### 81—Available Treatment of Malaria.

137. Only a very small proportion of the thirty million cases of malarial infection in the province receive treatment sufficient to afford them relief. A few thousands only get really adequate treatment in the larger hospitals and dispensaries ; under two million receive treatment which is wholly inadequate as far as the supply of quinine is concerned at some hundreds of smaller dispensaries throughout the province ; possibly 100,000 or so are attended by qualified medical practitioners ; but the vast majority of the sufferers from malaria receive either no medical attention whatsoever or are entirely dependent on such services as can be obtained from untrained village practitioners. A

very large number of sufferers from malaria who could afford better treatment rely instead upon one or other of the many quack remedies in the form of fever specifics which are widely advertised in nearly every newspaper as sure cures for malaria. These people usually enjoy the doubtful advantage of purchasing more or less ordinary quinine mixtures under fancy names at a price often ten times their actual value. In recent years the manufacture of spurious quinine tablets bearing a superficial resemblance to those prepared and sold by Government has come into prominence. Bakarganj district has sprung into notoriety in this connexion because of the number of manufactories of these bogus quinine tablets which have been discovered there and which have been sending out supplies of the spurious tablets to agents for sale in many other parts of the province.

### 82—Value of Quinine and Need of Improving the Supply.

138. From what has been stated, it will be apparent that the eradication of malaria from Bengal by the use of quinine is at present a proposition that is absolutely impracticable. But it must on no account be forgotten that quinine and the other cinchona derivatives are the most valuable medicinal remedies for malaria that the world has yet seen. A cheap and abundant supply of quinine and other cinchona alkaloids is therefore a necessity. Moreover, the Government of any malarious country that can secure such a supply and ensure that each individual in the population learns both the value of the drug and how best to employ it in case of necessity, confers an inestimable blessing upon its people.

139. Bengal must, therefore, face the problem of quinine supply. Much could be said in favour of increasing the manufacture of quinine and cinchona febrifuge. In view of the market price, it would pay to do this even if cinchona bark cannot be imported, for there are possibilities of further extending the plantations because cinchona *succirubra*, which yields the red bark, can be grown at relatively low elevations, some authorities giving 1,500 feet as the lowest limit. The red bark, although not so rich in quinine, yields a large supply of the other cinchona alkaloids which are equally as good as quinine, if not more efficacious in the treatment of malaria. Cinchona *succirubra* besides growing at a much lower elevation than cinchona *officinalis* and cinchona *ledgeriana* is also said to mature much more

rapidly, viz., in five years as against nine years. It is supposed that very little land is available for planting cinchona at the higher elevations required by C. *officinalis* and *ledgeriana*. It is possible, however, that a considerable area might be found capable of being planted out with C. *succirubra*. Enquiry might show also that the latter would grow in the Chittagong Hill Tracts. Both these possibilities are worth investigating.

### 83—Improving the Distribution of Quinine.

140. Meanwhile, the present manufacture and distribution of quinine and cinchona preparations require to be put on a proper business footing. The existing system of manufacturing the tablets is open to grave objections. Both the manufacture of tablets, etc., and their sale to the public should be controlled by one responsible officer possessed of business experience. The retail price should be fixed to allow a fair margin of profit after meeting all charges including that of advertising, and the controller of Government quinine should be given a motive for extending the sales by the grant of a suitable commission after the practice in commercial circles. The surplus profits on the Quinine Department should be used in the first place for extending the area under cinchona and so securing the future supply. When this has been done, they should be specially ear-marked, as in Italy, for furthering anti-malarial work of all kinds.

141. When the future supply has been secured, steps should be taken to organize a proper sale and advertising department, and further efforts should at the same time be made to extend the use of quinine in schools and dispensaries, and to organize a strenuous educative campaign in its favour by every possible means. There are more ways of educating the public in regard to quinine than by distributing it in schools and advocating it on posters, pamphlets and by lectures. The largest public can be reached by judicious advertisement, and I would strongly urge that this method be employed in addition to the other measures referred to. It is not the illiterate classes alone who require educating. In Bengal, a very large proportion of the literate population has an intense prejudice against quinine, and this prejudice is deliberately fostered by hundreds of vendors of quack medicines, who spread it through lying statements of all kinds, inserted in advertisements of their own remedies.

142. In Italy, not only has the Government adopted a policy of advertising the State quinine, but special laws have been passed, making it imperative for employers of labour in malarious localities to provide a free supply of State quinine for their employes. Employers in the tea districts already recognize their responsibilities in this direction, but it is otherwise in many areas, and Italian precedents should not be overlooked, when the question of quinine legislation is being considered. Some legislation in connexion with quinine is urgently needed, especially with a view to check the fraudulent sale of spurious quinine and similar preparations.

### 84—Combating Malaria by Anti-Mosquito Measures. The area to be dealt with.

143. We have now to consider the possibility of reducing malaria by specific measures of mosquito control. Some idea of the stupendous nature of the task may be gathered from an estimate of the area that would have to be covered by these measures in order to bring about the desired results. The total number of villages in Bengal, as shown by the census of 1911. was 119,334, distributed as follows :—

| | Villages | Houses | Population | Average houses | Average population |
|---|---|---|---|---|---|
| Western Bengal ... | 24,104 | 1,858,879 | 8,467 314 | 78 | 350 |
| Central „ ... | 13,341 | 1,703,921 | 9,445.321 | 125 | 633 |
| Northern „ ... | 39,081 | 1,869,633 | 10,138,302 | 47 | 259 |
| Eastern „ ... | 43,106 | 3,199,069 | 17,432,140 | 74 | 404 |

These figures are only approximate. In the case of the Presidency Division, 1,000,000 has to be deducted from the total population to exclude greater Calcutta and allow for obtaining the average village population.

144. An approximate estimate of the probable number of villages in which anti-malarial measures would be required may be obtained by using the fever indices of dispensaries in the different divisions. Each dispensary serves

a number of villages in its vicinity, and the fever index gives therefore some indication of the amount of malaria in these villages. Excluding areas in which the fever index of 1920 was under 20 per cent., we may say that the proportion of villages in each division in which anti-mosquito measures would be needed are as follows :—

| | | | | | | |
|---|---|---|---|---|---|---|
| Western | Bengal | 92 | per cent. or approximately | ... | 22,800 | villages |
| Central | „ | 97 | „ „ | ... | 13,000 | „ |
| Northern | „ | 84 | „ „ | ... | 33,000 | „ |
| Eastern | „ | 33 | „ „ | ... | 14,300 | „ |
| | | | Total | ... | 83,100 | „ |

145. From this estimate, we may safely conclude that measures would be required in at least 80,000 villages. Moreover, conditions are very bad indeed in a large proportion of these villages where the fever index is probably over 50 per cent., as the following statement will show :—

*Relative Intensity of Malaria in the 83,100 malarious villages of Bengal.*

*Estimated number of villages with fever indices exceeding 50 per cent.*

| | | | | | | |
|---|---|---|---|---|---|---|
| Western | Bengal | about | 15,000 | or approximately | ... | 18·0 per cent |
| Central | „ | „ | 5,600 | „ „ | ... | 6·7 „ |
| Northern | „ | „ | 4,000 | „ „ | ... | 4·8 „ |
| Eastern | „ | „ | 400 | „ „ | ... | 0·4 „ |

We have to consider therefore, the possible treatment of practically 70 per cent. of the total villages in the province, over 30 per cent. of which are very severely affected with malaria.

The various types of anti-mosquito work must now be discussed in detail.

### 85—Destruction of Adult Mosquitoes.

146. Mosquitoes may be destroyed by fumigation, or they may be caught in traps or in a hand net and afterwards killed. Fumigation has long been employed in Italy and the United States. The burning of resin is often resorted to Indian houses in order to drive away

*mosquitoes.* Unfortunately, it does not kill them. *Although the destruction of adult stegomyia mosquitoes* was of some service in campaigns against Yellow Fever Gorgas himself admits that too much reliance was at first placed upon this measure at Panama, and more effective measures aimed at the larvæ did not receive enough attention until experience showed that fumigation by itself was ineffective in checking the disease. The destruction of adult mosquitoes is even less useful in preventing the spread of malaria. "Hence," says Ross, "the expensive and troublesome process of fumigation is not much employed in malaria prophylaxis." At Panama, mosquito traps and the capture of mosquitoes by hand were used as subsidiary measures in the campaign against malaria. Traps are really of little value except for the capture of mosquitoes for the purposes of a survey or for laboratory work. The capture or destruction of mosquitoes by hand is also of minor importance and in the absence of other measures cannot make an appreciable difference to the spread of malaria.

147. Ross suggests that the offer of rewards of a penny (an anna) for 50 anopheles may quite possibly lead to a large slaughter by village children. It may also have a contrary effect. On one occasion, a planter offered a small monetary reward for the capture of anopheles only to discover after some time that one of the cleverer boys had learned how to breed large numbers in order to make money easily. Bats, birds, lizards, toads, dragon flies and certain other flies are known to catch mosquitoes. Bats have even been encouraged for this purpose in certain parts of California. But although these animals may reduce mosquitoes to some extent, no one can seriously suppose that they could be used as the main instrument for the control of malaria in Bengal.

### 86—Measures for Destroying Anopheles Larvæ : Larvicides.

148. Sir Ronald Ross was the first to propose the control of malaria by the destruction of anopheles larvæ ; and the methods suggested by him have been used with marked success at Ismailia, Panama, Havana and many other places. The treatment of collections of water with kerosene or crude petroleum is the simplest method and is now familiar to all. Other preparations may be used also, including emulsions of crude creosote, coal-tar disinfectants and solutions of certain chemicals ; but these are

generally more expensive than the oil. The cheapest campaign against mosquitoes by oiling was carried out some years since at Port Said, a place where there is little rainfall. The work cost about 5 pence (5 annas) per head of the population, which is a very low figure, impossible now that prices are so high. Even 5 annas per head of the population would amount to a very large sum in Bengal. In Calcutta alone, it would mean over 3 lakhs per annum, and in Bengal it would amount to nearly 1½ crores of rupees per annum. But this latter sum would not be anything like sufficient for the control of the dangerous anopheles mosquitoes in the province.

### 87—The Anti-malarial Campaign at Panama.

149 Turning to the very successful anti-malarial campaign at Panama, we learn from reports by the late Sir William Gorgas, who was in charge of the work, that the amount spent in the canal zone on anti-mosquito work alone was 2 dollars per head of the population per annum. Allowing Rs. 3 to the dollar gives Rs 6 per head. The population living in the malarious villages of Bengal is 30,000,000 and Rs. 6 per head on this population would amount to 18 crores of rupees per annum. On the basis of the whole population of Bengal, another 50 per cent. or a total of 27 crores per annum would be required. This sum is three times the total revenue of the province. No expense was spared at Panama. To quote Gorgas's own words—" When the canal shall have been finished, it can be shown that sanitation cost about $365,000 (£73.000) per year. For a population of 150,000. this means an expenditure of about 1 *cent.* (one half penny) per *capita* per day, and this sum is well within the means of any tropical country." But an expenditure of one half penny per head per day in Bengal is Rs. 11·4 per head per annum and this on a population of nearly 46½ millions is over 50 crores of rupees, or more than five times the total revenue of the province. Clearly such enormous sums as this are altogether outside the scope of practical politics. And though Gorgas's splendid achievement merits the highest praise, it does not afford an example that can be followed in Bengal in present circumstances. In recent years, the successful reduction of malaria by anti-larval measures has been reported from several areas in America at a cost per head of the population considerably lower than that expended at Panama. But even in these cases, the sums

found necessary ranged from about Re. 1-8 to Rs. 2-4 per head of the population. In Bengal, expenditure at this rate in the malarious areas only would require anything between 4½ to 6¾ crores per annum.

### 88—Estimate for Anti-malarial Work in Mauritius.

150. In 1909, Sir Ronald Ross visited Mauritius and drew up an estimate for an anti-malarial campaign in that island. His recommendations included partial prevention by quinine, but he relied mainly upon what he termed "minor measures" of anti-mosquito control. Mauritius has an area of 705 square miles, a population of 373,336 persons with a mean density of 534 persons to the square mile and a revenue in 1909 of Rs. 99,15,863, equal to Rs. 26·5 per head of the population. This revenue is in proportion 13 times as great as that of Bengal. With a similar rate of revenue, the Bengal Government would enjoy an income of no less than 120½ crores of rupees instead of nine crores as at present. "I estimated," says Ross, "that a general mosquito reduction in inhabited areas, especially towns, would cost, for minor works alone, the sum of £5,600 (Rs. 83,910) per annum. . . . . I advised that the workmen be formed into gangs of about three or four men each. One of the men should be appointed headman of each gang with extra pay and should be responsible for the work of the gang. . . . It is impossible to state how many gangs will be required for a given area. In Mauritius, I thought that one gang could manage about four square miles at a very rough average, and the cost of each gang was about Rs. 50 (£3·3) *a month. The gangs are to be superintended by mostiquiers or by special headmen if necessary.*"

151. Under the head of "*Cost*," he gave the following estimate of the work :—

| Items | Per annum Rs |
|---|---|
| (1) Salary of the malaria authority ... ... | 6,000 |
| (2) Salaries of 5 quinine dispensers ... ... | 6,000 |
| (3) Salaries of 15 mostiquiers ... ... | 4,560 |
| (4) Salaries of 109 gangs (327) ... ... | 65,400 |
| (5) Cost of quinine ... ... ... | 30,000 |
| (6) Preparation and despatch of quinine (say) ... | 3,600 |
| (7) Office of malaria authority ... ... | 1,500 |
| (8) Implements, etc., for gangs (Rs. 50 a gang) ... | 5,450 |
| (9) Travelling expense for staff ... ... | 2,000 |
| (10) Margin for possible calls ... ... | 10,490 |
| Total ... | Rs. 1,35,000 |

This expenditure for an area of only 705 square miles, rather less than an average subdivision of a Bengal district, worked out to 0·36 rupees per head of the population. Applying these figures to the case of Bengal, it would require almost exactly 1·6 crores of rupees per annum. As Ross' estimate was drawn up 12 years ago, long before the great rise that has since taken place in the cost both of labour and material, it is certain that it would have to be greatly increased at the present time. Probably, it would now have to be doubled. This would mean an expenditure over 3 crores per annum for Bengal. But even this sum would not suffice. Ross's estimate for anti-mosquito work was an exceedingly low one.

### 89—The Cost of Anti-mosquito Work in Dinajpur.

152. In Dinajpur town, where anti-mosquito work was carried on for several years by the Bengal Government, the actual expenditure was very much greater, yet the results were not appreciable. The report on the Dinajpur operations states :—

"In 1906, the Civil Surgeon, employing convict labour, had kept 40 men continuously at work for about 5 months of the rainy season. In 1908, Captain Reaney, I.M.S., had estimated for the employment of 10 men and a foreman throughout the year, 15 extra men and 3 extra foremen for 5 months, and an additional 40 men for one month. In 1909, an average of more than 28 men, rising to a maximum of 38 men, were employed throughout the year, and in addition from 2 to 5 mousquetiers were engaged. In 1910, an average of 22 men, rising to a maximum of 28 men, were employed. As the area dealt with was not more than 4 square miles this staff, which was much greater than that allowed for in Mauritius, should have been far more than were really necessary to give a fair trial to 'minor measures' of mosquito reduction." But on the evidence of the Civil Surgeons, who superintended the measures in Dinajpur, the number of men were not sufficient to do the work properly. Assuming that the Mauritius estimates were reasonable, it would appear that conditions in Dinajpur were much more difficult than any met with on that island. If this is so, it follows that the same conclusion must apply to nearly every municipality in Bengal, for with hardly an exception towns in that province offer difficulties as great as those to be met with in Dinajpur and many of them present even more serious obstacle to the successful carrying out of "minor measures" of mosquito reduction . . . . "The results obtained at Dinajpur support the conclusion arrived at with regard to the somewhat similar measures carried out at Ranaghat during 1906-1909. At the latter place, the minor measures of mosquito reduction

were finally discontinued, because it was found that they were not successful. In Dinajpur, although the expenditure on these minor measures, including the cost of supervision, amounted to an average of Rs. 1,680 per annum for each square mile of the area treated, the results were so doubtful that the work was discontinued. In view of this fact success must not be looked for from similar measures at a less expenditure unless conditions are specially favourable."

The expenditure on "minor measures" of mosquito control in Dinajpur, although on a scale ten times as heavy as Ross' estimate for similar work in Mauritius, did not prove strikingly successful. It is obvious therefore that a much larger amount than Rs. 3 crores would be required for Bengal as a whole, and that we could not now be certain of success with an expenditure of 16 to 30 crores of rupees on similar measures.

### 90—Destruction of Anopheles Larva by Small Fish, etc.

153. From time to time the suggestion is made that malaria can be controlled by introducing small fish, ducks or other natural enemies of mosquito larvæ into the collections of water in which these larvæ breed. "No cheaper and better anti-malaria measure," says Ross, "than the extermination of anophelines by natural enemies could be conceived or devised—were such a thing possible." "Unfortunately," he adds, "experience proves that animals and plants survive, even in large numbers, the introduction of their most deadly enemies; they succeed in finding some refuge or other, and a state of commensalism is finally arrived at." He cites Panama as an example where anophelines abounded in spite of the presence of hosts of fish which preyed upon them, and he also states that he "saw a ditch in Calcutta full of small fish and absolutely thick with mosquito larvæ; and have observed fish and larvæ living together in rice fields."

154. A considerable amount of study has been given to the mosquito-destroying fish of Bengal by Dr. Chaudhuri and others. Observations also have shown that these fishes are widely distributed both in the most malarious and less malarious areas. There are grounds for believing that the supply of fish generally has greatly diminished in many areas in Bengal. The reports of Sir Krishna Gupta and Mr. K. C. De, C.I.E., I.C.S., are both unanimous upon this point; one of the causes being the gradual drying up of the streams and

swamps and a general reduction of surface water, and if this is so the mere introduction of fish without a corresponding increase of water in which they could live, would not be likely to prove effective. As it is, almost every collection of water containing anopheles larvæ also contains one or other species of fish that preys upon them. It is only those ignorant of this fact who usually make the suggestion that malaria can be diminished by the introduction of fish.

155. Irrigation, it may be observed, would undoubtedly favour the increase of fish, and thus help to reduce the number of anopheles. In this connexion, the following quotation from a paper read by General Schangti-tong at the Paris International Congress of 1889 is not without interest :—

"I may add that without these gigantic irrigation works, the Chinese could never have carried to such a pitch of perfection one of their most important industries. I speak of pisci culture. Thanks to the abundance of water, the whole of my countrymen, instead of contenting themselves with covering with their fishing boats the seas, rivers, and lakes of our country, have devoted themselves to the breeding of fish. The spawn is every where carefully collected, far from leaving it to take its chance, the peasant gives this source of wealth a safe shelter in some spot where a perennial supply of water can be assured. The irrigation reservoirs teem with fish. During winter, the rice fields are fallow ; the water is led into them, and they are instantly full of carp. This industry allows us to make fish a considerable factor in the food of our people. The fish are either eaten fresh, or salted, and dried ; they are despatched to all parts of the Empire and sold at a price which is remunerative, though it is exceedingly cheap."

Obviously under the conditions depicted in the above passage, anopheles larvæ can have but little chance to multiply ; and it is possible that intensive pisci culture is one of the causes of the remarkable immunity from malaria enjoyed by the deltaic tracts of China.

### 91—Control of Anopheles Breeding Places by Draining or Filling.

156. Where feasible the control of anopheles breeding places by drainage or their permanent obliteration by filling them up with earth is always advisable. But a consideration of the facts shows that we cannot look to either of these measures for the control of malaria on a large scale

in the deltaic areas of Bengal. The vast majority of the infected villages are situated in the deltaic portions of each division, where, in the flood season, the level of the rivers is so high that drainage by gravity is out of the question. Drainage by pumping is utterly impossible not only because of the cost but owing to the fact that drying the land surface to a degree sufficient to prevent malaria would also prevent the cultivation of rice on which the population depends for its food supply. The village sites in the deltaic areas in which malaria is specially intense are riddled with ditches and borrow-pits of all kinds, and the filling up of the excavations in 80,000 villages is an absolutely impossible task. It is stated that some years ago a rough estimate was made of the cost of filling up borrow-pits, in the municipal areas only, of another province. It is reported that this estimate amounted to two years' total revenue of the province in question.

157. In recent years certain experiments have been carried out to determine the feasibility of reducing malaria in the more undulating country that exists in the extreme west and the north of the province. In the one case, at Singaran-Toposi, the scheme of work included the periodic flushing of the local river by means of a sluice, the filling up of numerous hollows and depressions and the drainage of many small swamps and other collections of water. By these means, a considerable reduction has been effected in the number of anopheles. And on general report there has been a corresponding diminution in the amount of malaria. But the disease has not been nearly eradicated as yet and, although the country dealt with covers considerably over one square mile, it now seems probable that this area is too small to allow the measures a chance of complete success. Similar conclusions have been arrived at in the case of Minglas, where under-draining has been chiefly resorted to and where, within an area covering 500 acres, anopheles breeding places have been almost entirely abolished by this method of draining. Here also the measure of success achieved at present is not sufficient to warrant the assumption that in places, such as this, where the infection rate is very high the total obliteration of anopheles breeding places over an area less than two square miles will serve to eradicate malaria. As the cost of measures of this kind is heavy and increases in proportion with the size of the area to be dealt with, it is clear that at present we cannot count upon eradicating malaria from Bengal by means of drainage and the filling up of hollows.

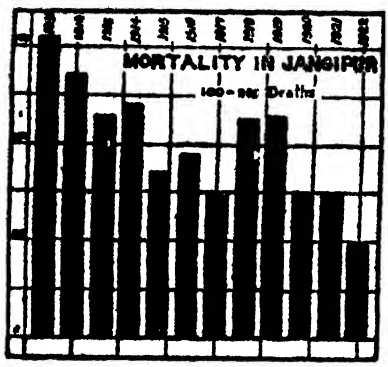
### 82—The Temporary Obliteration of Anopheles Breeding Places by Flooding or "Covering" with Water.

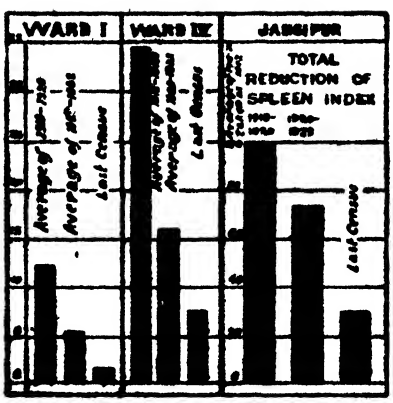
158. Attention has already been called to the good results obtainable by "covering" with water low-lying areas containing many small breeding places of anopheles. This measure has been in use for thousands of years. It was adopted in Europe long before anything was known about the causes of malaria. It was first employed with success by the ancient Greeks in a few localities and was afterwards used on several occasions both by the Italians and the Dutch. In recent years (as already mentioned in section 69) Celli, while speaking of its value, refers to the suppression of an epidemic of aquatic origin by the presence of water as a paradox requiring explanation. The explanation sought by Celli has now been given and is discussed at some length in paragraphs 65 and 66 of this report. "Covering with water" is Nature's method for controlling malaria in low-lying deltaic swamps. Every year this measure can be seen in action with the happiest results in vast areas in Eastern Bengal. Again and again in past years also the good effect on malaria of high floods in the rivers and copious inundations have been put on record by a host of medical men and other observers. Recently an attempt has been made to apply this method in the case of certain small areas in Bengal that have long been malarious. To this end a small scheme has been carried out at Jangipur and another of a rather different character in a portion of the Burdwan district. The effect of the work at Jangipur is spoken of favourably by the local residents. In 1918, the Head master of the high school stated that "the health of the town of Jangipur was good when all the surrounding villages as well as all places in this division were subject to the widespread ravages of influenza and malaria. But since the introduction of the anti-malarial scheme, the health of the town has considerably improved." In the same year, the Superintending Engineer in charge of the Banka Valley Scheme reported that :—

> "The regulator was used for regulating the depth of water on the land with the result that the crops, which otherwise would have been destroyed by heavy rain and floods in the Banka, have been saved."

159. The following extracts contain a brief summary of the results reported from Jangipur and the Banka Valley for 1919 :—

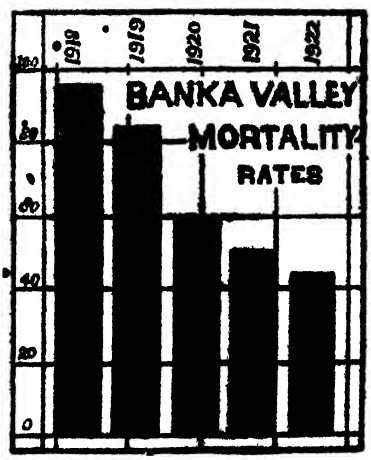
*Jangipur flood and flush scheme.*—This scheme for flushing out ditches, drains and tanks with silt-laden river water continues to give good results. One of the attached histograms indicates the death-rate of the town since 1911 and shows that, excluding 1918 and 1919, the year of influenza prevalence, there has been a substantial improvement since the scheme was first inaugurated.

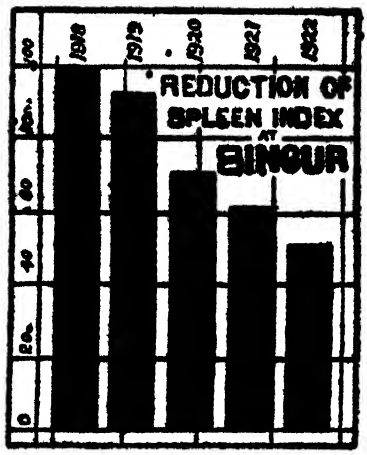



This improvement in the general health has followed upon a diminution of malaria, as may be seen from the second histogram which shows the relative reduction that has occurred in the spleen index of the town as a whole and particularly in the case of wards I and IV. In the two wards specially referred to, the spleen index has been reduced by over 50 per cent. during the last few years.

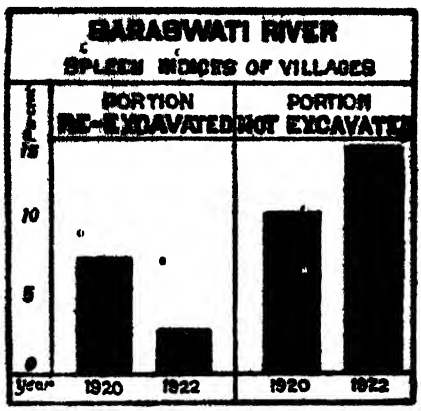
*Banka valley scheme.*—The Banka valley scheme also appears to be giving good results. One of the attached histograms indicates the recorded mortality of the whole




area since the work was first begun, and the other shows the steady and continued fall in the spleen index that has occurred at Singur, a village which is situated not far from the centre of the area. Both in the Banka valley and at Jangipur, instead of merely removing water by drainage in the ordinary way, provision has been made for the admission, during the flood season, of an increased amount of silt-laden river water into the area served. The same principle has also been recently adopted with remarkable success at Kumarkhali. The flushing of an unhealthy area was first tried in the case of the Kana Nadi as long ago as 1874-75 and proved completely successful. Good results were also obtained nearly 50 years ago by similar measures in the case of certain villages in the Rajshahi district, which had been attacked by an epidemic of malaria. Thus, it is recorded by Dr. Bensley, the Civil Surgeon, that the channels leading to a number of the tanks in the affected villages were re-excavated and fresh water brought in, and that after this the epidemic ceased. In view of these facts and the good results that have been obtained recently at Jangipur and Kumarkhali, and in connexion also with the Banka valley and the Saraswati river, there is every ground for believing that measures for improving the channels of water-courses and increasing the flow of water during the wet season, may be confidently expected to prove effective in the amelioration of malaria in Bengal.

*Saraswati scheme.*—Reference has been made to the work accomplished in connexion with the Saraswati river. A portion of the bed of this decaying river has been re-excavated in recent years and the flow in the channel has




greatly improved. The effect of this improvement upon the health of the adjacent villages has been excellent ; and as may be seen from the inset block, the aggregate spleen index of villages situated near the re-excavated portion of the river has undergone a material reduction pointing to the diminution that has occurred in the prevalence of malaria. On the other hand, in villages situated on the banks of the same river, but at points far removed from the re-excavated portion, there has been a marked increase in the spleen index during the same period. These successful experiments at Jangipur, Kumarkhali and Sarawati, respectively, prove conclusively that the firm belief of the country people in many parts of Bengal that the improvement of rivers and *khals* and the restoration of flow in their channels will reduce malaria, is founded upon a solid basis of fact Wherever, therefore, measures of this kind can be put into operation every possible encouragement should be given to carrying them out.

"Covering by water" is a measure that offers possibilities in connection with schemes of bonification in deltaic tracts where wet cultivation is the staple form of agriculture, and as we shall see later, the carrying out of irrigation projects will afford an opportunity for applying this method for the joint amelioration of malaria and improvement of agriculture.

### 93—Prevention of Malaria by Protection from the Bites of Mosquitoes.

160. Protection from mosquito bites can be secured by the use of mosquito nets, screening, fans and repellent oils and medicaments. The educated and well-to-do classes may protect themselves from malaria in this way to a great extent, but the poor will generally refuse the expense incurred. The cost of a good mosquito net is beyond the reach of the vast majority of the people, and the cheap nets now used by some of them soon wear out. The cost of screening a house is very heavy. Pankhas and fans are not practicable for the mass of the population and medicinal culicifuges are of little real value. The dwellings of the poorer classes are everywhere permeable to mosquitoes, and to protect such houses would cost as much as rebuilding the whole house. While therefore protection should be urged upon every one as strongly as possible, this measure cannot be considered as likely to prove immediately effective in reducing the malaria of the community as a whole to any great extent.

161 In Bengal, although the number of houses is stated to be about one for every five of the population, each house in the rural areas consists of a number of isolated huts. The cost of screening these huts or even providing a mosquito net for each of the inmates would mount up to a very large sum. To provide the cheapest form of net for the 30,000,000 people in the 83,000 malarious villages would cost at least 10 crores of rupees, and at the end of a year most of the nets would be useless. Obviously, therefore, protection from mosquitoes cannot be looked upon as a practicable measure of general malaria control for Bengal at the present time.

### 94—Co-operative Anti-malarial Societies.

162. Although financial considerations at present preclude the extended use of the majority of the specific anti-malarial measures referred to, it by no means follows that these measures are to be abandoned as useless. On the contrary, they must be adopted wherever possible, as far as means will allow. When a general finds that his available supply of ammunition or his heavy artillery is not sufficient to enable him to defeat the enemy by a frontal attack, he neither discards these weapons as useless nor wastes them in fruitless assaults. On the contrary,

he employs them when a suitable opportunity offers or husbands them carefully until such time as his resources can be increased sufficiently to enable him to employ them with a certainty of success. Every one of the anti-malarial measures that we have been discussing has its place in the campaign against malaria, and must be applied whenever it can be used to the best advantage. In this connexion, attention must be directed to an interesting movement for the formation of co-operative anti-malarial societies that has recently been initiated by Rai Bahadur Dr. Gopal Chandra Chattarji. The aim of this movement is to establish societies for mutual self-help against malaria; and for achieving this purpose many of the various measures referred to are being made use of as far as means will allow. This movement is full of promise. For, quite apart from the immediate results attained against malaria, it offers a valuable means of educating the public and gradually enlisting their help against the common enemy. The movement is at present in its infancy, but it merits every encouragement for it appears destined to become an important agency for the final eradication of malaria from the country. The fact that societies of this kind are in existence and are making an attempt to improve the localities in which they have been established is a most hopeful sign. And if the originator of the movement lives to see societies of this kind established in every village union throughout the province, he will have achieved his purpose and provided a most potent weapon by which the final control of malaria may be accomplished. Every endeavour should, therefore, be made to further the establishment of co-operative anti-malarial societies throughout the province.

### 95—Recapitulation and Conclusions.

163 To recapitulate: we have seen that probably over 80,000 villages are malarious and 30,000,000 people infected with the disease; to deal with this malaria by quinine would cost at least 1½ to 2 crores of rupees per annum for quinine alone, half of this amount being required in Western and Central Bengal; and the annual cost of the necessary staff would be at least half as much again and might even equal the cost of the quinine; this method of dealing with malaria would therefore entail an expenditure amounting to anything between 2¼ to 4 crores of rupees per annum; but a campaign of this sort is impracticable because quite apart from the question of cost, the

amount of quinine required could not be made available for many years to come; dealing with malaria on the lines suggested by Ross for Mauritius would cost at his original estimate 1½ crores per annum and at present prices double this sum or 3½ crores, and it could not prove effective for the reasons already given; anti-mosquito measures in the malarious villages on the latest American lines would cost between 4½ to 6¾ crores per annum; work on the lines of that carried out at Panama would cost 18 crores of rupees if confined to the malarious villages only; the general prevention of malaria by protection from mosquito bites is impracticable and even more costly than other methods; no reliance can be placed on the use of natural enemies of mosquitoes; the abolition of anopheles breeding places by filling-up is impracticable on account of the cost; and their treatment by drainage is equally impossible both on the grounds of cost and the physical difficulties to be overcome.

164. At first sight the position in regard to the amelioration of malaria in Bengal would appear far from hopeful. The total Government revenue is about 9 crores of rupees per annum. The total gross income of the population, calculated on the late Major J. C. Jack's estimate for the Faridpur district, would be about 240 crores per annum. Assigning an arbitrary value of Rs. 100 to the yield of each acre cultivated, would place the gross agricultural income of the country at about 290 crores per annum.

165. But allowing 50 per cent. extra in Eastern Bengal and 25 per cent. in Northern Bengal for the more valuable crops grown and the greater yield obtained owing to the fertilizing inundations would raise the estimate by another 100 crores to a total gross agricultural income of about 390 crores. Even on this latter figure, it will be at once apparent that the present resources of the conutry are totally inadequate for ameliorating malaria by the employment of costly direct attacks either upon the parasite or the anopheles mosquitoes that transmit it. All such measures, as we have seen, necessitate a very heavy outlay; and whatever their eventual effect may be on the earning capacity of the population, they cannot yield any direct return to Government in the way of increased revenue. This being so, recourse must be had to the only known method of anti-malarial sanitation, that is directly productive, namely bonification. Bonification offers the only alternative to a hopeless struggle against impossible

odds, or a policy of final resignation and despair. Moreover, it offers the one possible solution of the problem of Bengal malaria. And further, it promises an absolute certainty of success; because, while it is not only an effective measure in itself, it will also provide the resources needed for applying every other known method of malarial prevention for the final eradication of the disease.

# CHAPTER VIII.

## Bonification.

"Water is India's greatest treasure"

(SIR ARTHUR COTTON, R.E.)

"It is not the fault of the water if its natural circulation is interfered with; if certain portions of the land are drowned while others are left completely dry."

(WINWOOD READE.)

"There is not a single acre in India that would not be better for rich river water at some period of the crop, even when rain is most abundant, and that not only for rice, but for dry grains also."

(SIR ARTHUR COTTON, R.E.)

"If the careful regulation of the water is attended to, it answers admirably every requirement of the country, bringing prosperity to the population and revenue to the Government. Its necessary outlay in the cost of works is amply repaid over and over again, not only by the wealth but also the health of the territory where the money is spent."

(SIR ARTHUR COTTON, R.E.)

### 96—What Bonification is.

166. The idea of combining in a single scheme measures for the improvement both of agriculture and the public health originated with Leonardo da Vinci, who explained in the 53rd Chapter of his great treatise on the movement and measurement of waters: "How with the running water we ought to carry the earth of the mountains into the valleys, so as to render them fertile and to purify the air." The clearest statement of the principles of Bonification is to be found in Professor Mannaberg's classic monograph on malaria, which contains the following striking passage:—

"It was the cultural activity of the race that converted severely infected, death-dealing malarial foci into salubrious, thickly inhabited territories. The general prophylaxis of malaria would, up to the discovery of the mosquito malarial cycle, be stated in one word 'cultivation', and this in a sense is still true. All these old and well-tried methods had this common aim, the regulation of the ground moisture so as to promote fertility. These regulations were to be accompanied by cultivation without which the end was rarely

attained. The ground could not be left as pasture but had to be systematically planted with grain, sugarcane, eucalyptus, etc. The special properties of the soil and the climatic conditions of the locality decided the choice of the plant. These hygienic regulations occasionally produced extraordinary results. The cultivation of the ground from this, the old stand point, might be designated as a second important factor in prophylaxis. It was well known that when cultivation is neglected even healthy regions pay the penalty of infection. The extensive clearing of forests especially has drawn in its wake serious results for the neighbourhood. In swamps where drainage was impossible, a regular level was aimed at, especially during the summer months, by the regulation of the incoming and outgoing water, and by the building of dams, since it was not the surface covered with water, but that which was alternately under water and exposed to evaporation which was (supposed to be) dangerous. Exceptionally during severe epidemics, radical measures were undertaken, as for instance, the copious flooding of malarial foci. This was first put into practice by Empedocles, later by Lancisi."

167. In a report on the "utilization of river silt for the fertilisation of land and the mitigation of malaria" the late Sir Edward Buck defines "Bonificazione" as "the improvement by drainage and by silt deposit not only of the agricultural value of the land treated, but, also as a rule, of the climate of the area dealt with." Mr. C. H. Hutton, C.I.E., of the United Provinces Irrigation Department, who has reported on the utilization of silt in Italy, states "By the term Bonificazione is meant, in a general way, the improvement of land, either from an agricultural or hygienic point of view, or from both together." There is no mystery in "Bonificazione." It is merely certain old and well-tried principles under a new name. Those principles are the regulation of surface waters and the promotion of cultivation referred to by Mannaberg. Bonificazione is not the monopoly of Italy nor the invention of Italian engineers, although the world owes much in this connexion both to that country and the genius of her people.

"Nothing can be more evident," said Sir Arthur Cotton over sixty years ago, "than that upon the regulation of water all pro luce depends ... Every acre of land in the world requires irrigation and drainage. Not a year passes that there are not both excess and deficiency of water at different times. Upon the regulation of the waters of every country depends uncomparably more than upon anything else the well-being of it, and this is especially the case in all tropical and other countries which have well-defined periodical rains."

In these few words, the great irrigation expert, whose magnificient achievements saved both Tanjore and the

Godavari delta from agricultural decay and depopulation, lays down this fundamental principle of water-regulation and agricultural improvement implied in the "Bonificazione" of the Italian engineers.

168. Bonification does not necessarily require the employment of special or peculiar systems of engineering, or the cultivation of any particular kind of crop. "Experience teaches that the soil is the more insalubrious the less it is cultivated" says Mannaberg. But under the head cultivation he includes much more than is ordinarily implied by that term, viz., the regulation of the ground moisture, the promotion of soil fertility, the raising of crops and even the number and condition of the population concerned in the work. Further, the regulation of water is to be accomplished by canalization and drainage, and in the case of swamps both the incoming as well as the outgoing water must be regulated either by dams and other means, and if necessary flooding must be resorted to. For the purpose of bonification, the growth of crops is better than pasturage and, though certain crops are mentioned as specially suitable, the guiding principles that must determine the choice of the crops to be cultivated are climate and the conditions of the soil.

169. Bonification, therefore, consists in (1) the regulation of all surface waters, (2) the improvement of the fertility of the soil, (3) the cultivation of those classes of crops best suited to the local conditions, (4) and the promotion both of the increase and the prosperity of the resident agricultural population. Hence any measure, whatever its character, provided it will stimulate agriculture and encourage cultivation, making the soil yield the highest possible return to the local agricultural population and thus promoting their health and their prosperity, is "bonification" in the truest sense. It is these general principles of water regulation and of agricultural improvement that must be applied in the case of Bengal for the amelioration of the associated evils of malaria, agricultural decline and depopulation.

### 97—Bonification a Productive Measure.

170. It will be gathered from what has been stated that bonification is a productive measure. It is, moreover, the only anti-malarial measure that is productive. Hence it is specially adapted for the reduction of malaria in rural areas, where non-productive measures of sanitation are often impossible on a scale adequate for the occasion because of the heavy cost and the large area to be dealt

with. Productive measures naturally fall into two categories: those that afford a direct monetary return on the capital outlay involved, and those that while not necessarily being directly remunerative, yet add enormously to the general prosperity of the community and yield indirect returns perhaps far in excess of their initial cost. Bonification is productive in the latter sense and may conceivably fall under the first category also, provided considerations of administration allow. In connexion with this question of the relative productiveness of large measures aimed at promoting the public welfare, the following passage relating to irrigation in Egypt is of special interest.

"The Government", says Sir William Willcocks, "does not consider only the direct gains from taxation (*e.g.*, the land tax), it considers the increased transport on its railways, the increased import of necessaries, the increased use of duty-paying luxuries like tobacco, the diminished losses of revenue in years of scarcity and the improved well-being of its population. India, as a rule, does exactly the opposite. With rare exceptions, it calculates the expenditure and revenue of its projects on commercial lines just as though it had only direct taxes to deal with; and on this account rejects project after project in the tracts where they are most needed and carries them out where they pay best whether they are needed or not." In a later passage, the same author suggests what might be done in India in the way of providing really productive works of irrigation. "If Government", he says, "could take advantage of the fact that the first heavy falls of monsoon rain on a dry and friable soil fills the rivers in their early stages with water, which is in great part manure, by building suitable works on the rivers and their tributaries it might lead these waters over the poor worn-out soils and give them a new lease of life. All these projects would not pay as irrigation enterprises, but they would pay a hundred-fold indirectly. Famine expenditure would be reduced beyond recognition, and the successful completion of our projects would show the way for developments unthought of to-day. These would be no visionary projects. They would be sound investments."

### 98—Examples of Bonification: the Val di Chiana.

171. The best known examples of bonificazione are naturally to be found in Italy, the Val di Chiana being the oldest and the most successful. The Val di Chiana has

been entirely reclaimed by the regulation of the surface water and the deposit of silt. Sir Edward Buck quotes the official report to the effect that "all the transformations have been due to the natural deposit of silt spread over the land by lateral streams directed more or less by man." Torricelli, a pupil of Galileo, was the first to study the question of silt deposit, but it was not until the close of the eighteenth century that malaria was expelled from the Val di Chiana by this means, and even then much in the way of levelling and draining and irrigation still remained to be done. The latter work was designed by Fossombroni and was carried out by Manetti and other able Tuscan Engineers in comparatively recent times. Baird Smith did not visit the valley during his Italian tour, giving his reason for not doing so the fact that "Manetti informed me that I would see only results. as the whole of the works there had been finished for some time, and with the most remarkable success, the entire valley having been restored to culture, occupied by an industrious and now healthy population, with the low marshy localities all filled up and the waters under perfect control." The Val di Chiana is now one of the most fertile, densely populated and prosperous agricultural districts in Italy It covers about 800 square miles, the greater part of which is cultivated, a portion being irrigated and devoted to rice crops. The population, which is composed of small cultivators, exceeds 600 to the square mile. It is an area of special interest to malaria experts, not only because it is a striking demonstration of the beneficial result of bonificazione, but owing to the fact that it affords an example of "Anophelism *sine* malaria," anopheles mosquitoes being present in considerable numbers whilst malarial disease is almost unknown. Probably the Val di Chiana is still potentially malarious, but the perfect control of the surface waters, the fertility of the land and the resulting density and prosperity of the resident agricultural population serve to keep down the spread of infection so that the area remains free of the disease.

### 99—Further Examples of Bonificazione: the English Fens.

172. In many other countries besides Italy, the principles of bonification have been applied with the greatest success. The Fen districts of England, the polders of Holland, the whole of lower Egypt and the deltas of the Cauvari and Godavari in Madras each afford striking

examples of this fact, although in all these cases the work was undertaken primarily for agricultural purposes and largely for the sake of monetary profit. In England, for example, the reclamation of the Fens was begun at the time when the price of wheat was high and the shipment of corn to the Continent was being encouraged by the offer of Government bounties. But though originally a financial speculation, the work accomplished has none-the-less been entirely successful in ridding the country of the "ague" which formerly prevailed there.

173. The fens of Eastern England comprise over 680,000 acres of land, which was formerly inundated by the joint action of the rivers and the sea. They are now productive lands dotted over with towns and villages. Their reclamation extended over a period of two centuries. Before attempts were made to reclaim them, the rental value of the fen lands was estimated at four annas to twelve annas per acre. After reclamation, their value rose rapidly, first Rs. 9 to Rs. 12 per acre and in 1849, the average rental was stated to be Rs. 30 per acre.

174. The first stage of reclamation was the construction of embankments, drainage being effected by gravity through drains provided with sluices. Eventually owing to the natural shrinking of the soil, that takes place in low lands that have been drained and cultivated, gravity drains ceased to perform their function and it became necessary to install pumps to lift the water from the low lands into the main ditches. It has been found, as a matter of experience, that the level of the sub-soil water or the water-table in fen lands should be kept within 24" or 30 inches below the surface. The Black Sluice District is a typical fen district. It is a strip of level marsh, originally a lake or *bil* about 4 miles wide and twenty-one miles long. The total area which now discharges its waters through the main sluice into the Witham River is 134,351 acres, but the area liable to taxation in respect of reclamation is 64,854 acres. The district is drained by a main drain, called the "South Forty Foot," which has a length of 21 miles, with a grade of 3 inches per mile. This drain discharges into tide-water near Boston through the Black Sluice, which has three gates each 20 feet wide. The interior drainage of the district is accomplished through the organisation of small sub-districts bearing local names, as "Morton Fen," "Dowsby Fen," etc., which all use the main drain as an outlet and pay a tax for its construction and maintenance. The amount of

tax for the construction of the main drain was assessed on the theory that the land most distant from the outlet should pay the greater tax. Numerous pumping stations are operated to accomplish the drainage of the "fens" or drainage sub-districts.

175. Seepage water from the surrounding higher lands is intercepted by a ditch, which is called the "Car Dyke." This ditch extends along the base of the slope and discharges its water into the river through an independent sluice; upland water is thus prevented from passing into the low lands and flooding them. Many streams, which carry what is termed "live water" in contradistinction to semi-stagnant swamp water, intersect the area and in many cases are carried across the fens on a higher level. Such streams are called "lodes". During dry seasons, water is taken out of these "lodes" through small sluices for irrigation purposes.

### 100—Bonification in Holland.

176. In the case of Holland, similar measures to those used in the English fen districts, applied from similar motives and on an even larger scale, have been productive of similar beneficial results to agriculture and health. As in England, the methods of bonification employed in Holland consist largely of improved systems of drainage whereby low country, which would otherwise remain waterlogged and unproductive, has been turned into rich farmland. To achieve this purpose, rivers and estuaries have been embanked, the low country has been covered with a net work of high level drains and canals connected with the rivers, and the excess water from the field is pumped up into the drains. Formerly windmills were employed for the purpose of pumping, but in later years steam has largely replaced wind as a motive power. The drainage of Haarlem lake is a striking example of bonification by embankment and drainage, the latter process being accomplished by pumping. The lake was formerly a body of fresh water, 14½ miles long by 8 miles at its greatest width, with a maximum depth of 13 feet. It covered an area of 43,700 acres. It was reclaimed in the following manner: First, an embankment was constructed around the lake for a distance of 37 miles. Outside this a navigable canal was excavated into which the water of the lake was to be pumped, sluices being provided to allow for the escape of surplus water from the circular canal into the North Sea

Canal and the Rhine, respectively. A road encircled the lake midway between the canal and the embankment. The cost of the embankment and canal was approximately Rs. 24,22,500. In order to empty the lake and provide for subsequent drainage, three pumping stations were established, one at the north, one at the south and one on the west side, each with a 350 horse power plant. The lake was pumped dry after 39 months, the engines having been actually in operation for 19½ months. Main drains were afterwards provided in the bed of the lake running north and south and east and west, and numerous smaller ditches were connected up to them. Roads were also constructed. The land was divided into fields of 50 acres. The extent of the works may be stated as follows:—

| | | Miles |
|---|---|---|
| Total length of encircling canal and embankment | ... | 37 |
| " " " large canals leading to the pumps | ... | 18·6 |
| " " " main canals ... | ... | 93·1 |
| " " " all canals and drains ... ... | ... | 750 |
| " " " roads ... ... | ... | 122 |
| Number of bridges ... ... | ... | 65 |
| " " pumping plants ... ... | ... | 3 |

177. After the reclamation was completed, the lake bottom was sold by the Government at public auction at prices ranging from Rs. 200 to Rs. 400 per acre, the average price being Rs. 250 per acre The amount expended in actual construction was about Rs. 120 lakhs, and interest charges, commissions, amortization of capital cost, etc., rather more than another Rs. 55 lakhs. The total cost of reclamation was thus about Rs. 175 lakhs. The amount derived from sales of land, rent, etc., was nearly Rs. 120 lakhs, and the net cost to the Government was about Rs. 130 per acre.

"About 16,000 people," says Elliott, "now occupy this unique domain lying 12 feet below the level of the sea. Two towns in addition to the numerous farmsteads located along the main roads give an appearance of thrift and comfort to the entire area."

178. Although Holland is now free from malaria, that country like almost all delta tracts is potentially malarious. A remarkable example which illustrates this occurred in Holland in 1748. Thus Deadrick records that :—

"The Dutch allowed the land, for defensive purposes, to become overflowed. Peace being concluded during the middle of the summer the inundation was caused to subside, whereupon a serious outbreak of malaria occurred. The epidemic was not combated until the land was again submerged and kept so until the advent of winter."

## VI.—Warping, a Special Method sometimes used in Bonification.

179. Besides drainage by pumping, certain other engineering expedients are sometimes employed for improving low-lying country, including what is known as "warping". Warping is the equivalent of the "Colmatage" of the French and the "Colmata" of Italian Engineers. Owing to the frequency with which this method has been employed in Italy for the purpose of improving the agricultural land of malarious areas, it has often been referred to by English writers as "bonificazione" (*vide* pages 99—105 of Lt. Col. F. C. Hirst's Report on the Nadia Rivers). "Warping" or "Colmata" is, however, only one of many different engineering expedients for carrying out the general principles of bonification in certain special circumstances. Below is a brief description extracted from the British Encyclopædia of the method of warping as carried out in England :—

"The best notion of the process of warping may be gained by sailing up the Trent from the Humber to Gainsborough. Here the banks of the river were constructed centuries ago to protect the land within them from the encroachments of the tide. A great tract of country was thus laid comparatively dry. But while the wisdom of one age thus succeeded in restricting within bounds the tidal water of the river, it was left to the greater wisdom of a succeeding age to improve upon this arrangement by admitting these muddy waters to lay a fresh coat of silt on the exhausted soils. The process began more than a century ago, but has become a system in recent times. Large sluices of stone with strong doors, to be shut when it is wished to exclude the tide, may be seen on both banks of the river, and from these great conduits are carried miles inward through the flat country to the points previously prepared by embankment over which the muddy waters are allowed to spread. These main conduits, being very costly, are constructed for the warping of large adjoining districts, and openings are made at such points as are then undergoing the operation. The mud is deposited, and the waters return with the falling tide to the bed of the river. Spring tides are preferred, and so great is the quantity of mud in these rivers that from 10 to 15 acres have been known to be covered with silt from 1 to 3 feet in thickness during one spring of 10 or 12 tides. Peat-moss of the most sterile character has been by this process covered with soils of the greatest fertility, and swamps which used to be resorted to for leeches are now, by the effects of warping, converted into farms and fertile fields . . . The immediate effect, which is highly beneficial, is the deposition of silt from the tide. To ensure this deposition, it is necessary to surround the field to be warped with a strong embankment in order to retain the water as the tide recedes The sluices are placed on as low a level as possible to permit the most turbid water at the bottom of the tide to pass through a channel in the base of the embankment. The silt deposited after warping is exceedingly rich and capable of

carrying any species of crop. It may be admitted in so small a quantity as only to act as a manure to arable soil, or in such a large quantity as to form a new soil. This latter acquisition is the principal object of warping, and it excites astonishment to witness how soon a new soil may be formed. From June to September a soil 3 feet in depth may be formed under the favourable circumstances of a very dry season and long drought . . Warp soil is of unsurpassing fertility. After the new land has been left for a year or two in seeds and clover, it produces great crops of wheat and potatoes."

### 102—Bonification in Egypt.

180. In Egypt, "bonification" has taken the form of irrigation. A peculiar system of flood irrigation known as "basin irrigation" has been practised there from time immemorial with the triple advantages of providing manure for the fields, moisture for the crops and immunity from malaria. Winwood Reade writes as follows of the Nile in ancient Egypt :—

"In the Winter and Spring, it rolls a languid stream through a dry and dusty plain. But in the Summer an extraordinary thing happens The river grows troubled and swift, it turns as red as blood and then green ; it rises, it swells, till at length overflowing its banks it covers the adjoining lands to the base of the hills on either side. The whole valley becomes a lake from which villages rise like islands, for they are built on artificial mounds. This catastrophe was welcomed by the Egyptians with religious gratitude and noisy mirth ; when the fields had entirely disappeared, they thanked the gods and kept their harvest-home. The tax gatherers measured the water as if it were grain and announced what the crops and the budget of the next year would be. It was then also that white robed priests bearing the image of a god, and singing hymns, marched with solemn procession to the water side and cast in a sacrifice of gold. For the water which had thus risen was their life. The bread of the people ... depended on the amount of the inundation. They devised a system of dykes, reservoirs and lock canals by means of which the excessive waters of a violent Nile were turned from the fields ; thus also the precious fluid was conveyed to tracts of land lying above the level of the river and was distributed over the whole valley with such precision that each lot or farm received a just and equal share. Agriculture became a mathematical art ; it was ascertained that so many feet of water would yield so many quarters of corn ; and thus before a single seed was sown, they could count up the harvest as correctly as if it had been already gathered in."

181. "Regularity of flow", says the Encyclopædia Britannica, "is the first exceptional excellence of the river Nile. The second is hardly less valuable, and consists in the remarkable richness of the alluvium brought down the river year after year during the flood. The object of the engineer is to so utilize the flood water that as little as possible of the

alluvium may escape into the sea, and as much as possible may be deposited on the fields. It is the possession of these two properties that imparts to the Nile a value quite unique among rivers, and gives to the farmers of the Nile valley advantages over those of any rain-watered land in the world."

### 103—Lord Milner's Account of Basin Irrigation.

182. Lord Milner, writing of the Nile in his well-known book on Egypt, says "The river is not only the irrigator, but the fertiliser of the soil. The reddish-brown mud which the Blue Nile washes down from the volcanic plateaus of Abyssinia, mixed with organic matter from the swamp regions of the White Nile, does more than any manure can do for the annual renovation of the land . . For thousands of years the agriculture of Egypt depended entirely upon the unaided action of the river. The valley was intersected by dykes, running at right angles to the Nile, and forming with the embankments of the latter, and with the rising desert land which bounds the valley on either side, a series of basins so contrived as to regulate the course of the flood and to compel it to deposit the rich matter, with which it was charged. These basins were in a series of chains, each chain being fed by a separate canal from the river, and having a separate escape, by which the water, after doing its work, was let out into the river again In some, but not in all cases, communication was also provided from the bottom basin of one chain to the top basin of the chain immediately below it. By these means, the water was retained upon the land, which was generally flooded for six or seven weeks, till it was covered with a thick coat of rich mud. On this mud, after the water had run off, the seed was cast, and the husbandman had nothing to do but to tend his crop and in the fulness of time to harvest it . . Cultivation cost little in labour and nothing in manure. The flood annually revived the soil and kept it perpetually in heart . . Colonel Ross had constantly to keep in view two distinct objects, not always easily combined. The first was to make sure that every basin—and he was dealing with a hundred and twenty of them varying in size from five hundred to thirty-five thousand acres—should, even in a year of low Nile, be adequately flooded. The order was to give to every part of each basin, as far as possible, not merely water, but water of the 'red' or fertilising quality. Whether the water he receives is "red" or white makes a

vital difference to the agriculturist of upper Egypt. The 'red' water (I think we should call it brown) is that which has not yet deposited its precious mud, the annual regenerator of the soil. The 'white' water is that which has already parted with its mud. Land inundated by 'red' water every year, for a sufficient time, never deteriorates. Land inundated only by 'white' water rapidly becomes exhausted. In traversing the fields of upper Egypt, any observant traveller must be struck by the remarkable contrast often exhibited in the quality of the crops on adjoining lands where all the natural conditions appear at first sight to be identical. On enquiry, it always turns out, that where the crops are poor, it is due to some defect in the irrigation works, or perhaps to some insuperable disadvantage of situation which has prevented these particular fields from being inundated with 'red' water."

### 104—The Advantages of Bonification by Irrigation in Egypt.

183. Egypt has passed through many vicissitudes. On account of the extraordinary fertility of the country, ancient Egypt was known as the "Granary of the World." At the time of the Arab conquest in the 7th century A.D., the whole country was cultivated, but between 700 A. D. and 1800 the population of 12,000,000 had dwindled to 2,000,000, and irrigation had been abandoned over the great part of the delta. Now-a-days, thanks to irrigation, Egypt is again prosperous and for her size is one of the richest agricultural countries in the world. "Egyptian irrigation", states Sir Hanbury Brown, "is a subject which all must study who wish to understand the causes of Egypt's recovery from a state of bankruptcy to wealth." Although the reckless finance of Ismail Pasha raised the public indebtedness to about £100,000,000 in 1863, of which only about £40,000,000 was spent on reproductive works, this extravagance has not stopped progress. The Egyptian debt now stands at £94,972,000, on which the annual charges are £ 3,490,325, and about £ 300,000 per annum is now devoted to its reduction. But in spite of debt Egypt is very prosperous. The revenue of the Egyptian Government from all sources was £15,965,700 in 1910 and the expenditure £14,414,500, leaving a surplus of £1,551,200. The population of Egypt in 1907 was 11,287,359 with a mean density of over 940 to the square mile. The rate of increase between 1897 and 1907 was 16·2 per cent. Since 1907 the population has increased by a further 14 per cent.

The total value of imports in 1910 was, over £ 23,553,000 and that of exports £ 28,941,000.

184. Excluding desert, Egypt is no larger than the Presidency Division, but the country now possesses nearly 3,000 miles of railway and 1,800 miles of roads. In 1897, the rent on 4,550,181 acres was £ 16,356,000. The land tax amounted to 28·64 per cent. of the rent, and equals about £ 0·83 or Rs. 12-8 per acre in Upper Egypt and £ ·97 or Rs. 14-8 in Lower Egypt, the average being £ ·91 or about Rs. 13-8. The average rent of agricultural land is £ 3-10 or Rs. 52-8 per acre, and the average selling value is about £ 50 or Rs. 750 an acre. The total cultivable area of Egypt is 6,663,000 acres of which 5,351,000 are cultivated. There are three crops in the year. In the winter about 3,600,000 acres are under wheat, beans, barley and clover; during the summer 2,183,000 acres are under cotton, millets and maize, sugarcane, rice and miscellaneous crops, and in the flood season 1,700,000 acres are cultivated with rice, millets and maize. Orchards and gardens cover another 80,000 acres. The gross cropped area is thus 7,662,000 acres. Cotton is the most valuable non-food crop, 30 per cent. of the net cropped area and 20 per cent. of the gross cropped area being devoted to it. The annual value of the cotton crop ranges from twenty to twenty-eight million pounds and averages about £ 2 per head of the population.

185. All this has been rendered possible by the irrigation system which controls the Nile and regulates the supply of silt-laden water to the land. The value of the silt deposited on an acre of land by Nile flood-water, when considered as manure at soluble commercial fertilizer rates, is, according to agricultural authorities, worth as much as £ 1-10. Land situated in basins which receive a full supply of red muddy flood-water fetches nearly twice the rent paid for land which gets no "red water". In 1910, the recurring expenditure on irrigation amounted to just about Re. 1 per head of the population. In the same year the Government expenditure on Police and Prisons was equal to about annas 15 per head; expenditure on Justice about the same; expenditure on Education was about 10¼ annas per head of the population; expenditure on Public Health about 6¼ annas per head; and expenditure on Communications other than railways, about 1 anna per head. The railways, most of which belong to the State, paid a surplus of £ 1,829,900. In 1920, expenditure on Public Health was estimated at £ 720,425 or Rs. 1,08,06,375. which

is about 8·5 annas per head of the population against the 1·5 annas per head allowed in Bengal for both medical and sanitary purposes together.

### 105—Malaria and Anopheles in Egypt.

186 The delta of the Nile has enjoyed almost complete immunity from malaria for centuries, probably as a direct consequence of the irrigation system just described. Strabo mentions in his Geography (written in the first century B. C.) that Alexandria although surrounded with swamps was yet free of marsh fever. Forty years ago, Hirsch ascribed the immunity from malaria enjoyed by Egypt to the effects of the Nile inundations in the following words :— "

"When the water is high and the ground completely covered by it, the endemic or epidemic disappears, fresh cases of the disease appearing only after the water has run off and the surface of the ground has been laid bare. Classical examples of this are furnished by the malarious regions periodically inundated on the banks of the Nile, Indus, Euphrates, Ganges, Senegal, Niger, Mississippi and other rivers, where the endemic always begins after the waters have begun to subside."

"The primary effect of the submergence of land", says Deadrick, in his recent text-book on Malaria, "is to diminish malaria. The effect upon malaria of inundations is almost yearly observed in the valleys of the Nile, of the Mississippi and of other large streams."

In the Annals of Tropical Medicine and Hygiene for November 1909, Day and Ferguson refer to the remarkable freedom from malaria of Lower Egypt in the following words :—

"The comparative rarity of malaria in Cairo may be gauged from the fact that not more than one or two cases are seen at hospital in the course of a year."

187. But like other delta areas, Egypt is potentially malarious. Dr. H. C. Ross points out that in March 1907 anti mosquito work was started at Heluan because malaria existed there. "Anophelines had been taken and examination of blood-films taken at random from native children demonstrated benign parasites ; an examination which had been made previously by Dr. Dreyer of the Public Health Department . . In September '1907, Dr. Dreyer again examined blood-films from some children in Heluan and found that very few parasites could now be demonstrated."

"Malaria exists," says Dr. Ross, "but it is only of the mild tertian and quartan types. Following on some questions which were asked

in the House of Commons last year, a controversy arose in the Press in Egypt regarding the incidence of the disease. One paper said that it did not exist. But it does. Only last summer an outbreak occurred at Ghezireh, and according to the Statistical Report of the Public Health Department for 1908, twenty-nine deaths occurred in Cairo alone from the disease. The Senior Medical Officer of the Egyptian Army reported an outbreak at Zeitoun and Abbassieh (suburbs of Cairo) on 3rd November 1907. I have myself seen cases of malaria, and have taken anophelines frequently, especially at Ghezireh."

188. These facts show that malarial infection and anopheline carriers of the parasite are actually present in Egypt. The amount of malaria is, however, insignificant, showing that conditions are unfavourable to the spread of the disease. This conclusion is supported by the latest medical statistics. The following table which is extracted from the Annual Report of the Egyptian Department of Public Health for the year 1919 shows the total number of malaria cases (not deaths) reported from various parts of Egypt during that year :—

**Malaria cases in Egypt during 1919.**

| | | | | | |
|---|---|---|---|---|---|
| Cairo ... | ... | 11 | Brought forward | | 285 |
| Alexandria | ... | 4 | Sharqiya | ... | 24 |
| Ismailia ... | .. | 29 | Dakahliya | ... | 3 |
| Port Said | ... | 27 | Giza ... | ... | ... |
| Damieta | ... | 15 | Beni Suef | ... | 2 |
| Suez ... | ... | 149 | Faiyûm | ... | 28 |
| Eastern Province | .. | 1 | Minya ... | ... | 18 |
| Behcira ... | ... | 12 | Asyut ... | ... | 11 |
| Gharbiya | .. | 18 | Girga ... | .. | 4 |
| Minufiya | ... | 17 | Qena ... | .. | 5 |
| Galyabiya | ... | 2 | Aswan | ... | 1,304 |
| Carried forward ... | | 285 | Total | ... | 1,684 |

189. The figures cited relate to cases of disease only not deaths. The bulk of the cases recorded occurred far up the Nile valley, above the first cataract, in a strip of country on both sides of the river extending for a distance of about 65 miles and inhabited largely by Arabs. The comparative rarity of malaria, in the lower portion of the valley and the delta proper, may be gauged by the fact that among the patients admitted for treatment at dispensaries and hospitals in Egypt only one per cent. were

cases of malaria. The fever indices of these dispensaries are given below :—

**Fever Indices at Dispensaries in Egypt.**

| | Per cent. | | Per cent. |
|---|---|---|---|
| Alexandria .. | 0·6 | Qalyabo | 2·4 |
| Suez ... . | 6·1 | Abbasnyaha | 0·9 |
| Port Said . | 1·6 | Beni Suef | 0·4 |
| Damieta . | 4·7 | Fayum | 1·8 |
| Tanta . | 1 5 | Minya | 1·3 |
| Damahahir . | 0·8 | Asyut | 0·5 |
| Mansura . | 0·7 | Sahag | 0 1 |
| Zagazig . | 0 6 | Quena | 0·7 |
| Shibin ... | 0 9 | Isna | 0 3 |
| I. J. E. Co., Zagazig | 1·6 | Aswan | 3 1 |
| Berha . | 0·9 | | |

190. In spite of the small prevalence of malaria in Egypt it is most significant of the remarkable prosperity of that country that, in 1919, the Egyptian Anti-malarial Commission had funds placed at their disposal amounting to no less than £21.000 (Egyptian) equal to nearly Rs. 3,23,000. Of this sum, £5,000 was devoted to Cairo and the neighbouring district ; £1,739 to the Suez Canal Zone ; £10,161 to the other district headquarters; and £2,100 to the Oases. In addition to this, £1,000 was allotted for a survey of the mosquitoes of Egypt.

**106—Anopheles Mosquitoes in Egypt.**

191. Like many parts of Eastern Bengal Egypt remains free of serious malaria in spite of the presence of anopheles mosquitoes. In a paper upon the mosquitoes in the neighbourhood of Cairo, published in the "Annals of Tropical Medicine" (March 1910), Mr. Willcocks, Entomologist to the Khedival Agricultural Society, states that :

"Although *Cellia pharoensis*—a supposed malaria carrier—was very abundant in the autumn of 1908 in Ghazirah, yet, so far as the writer is aware, there were no cases of malaria reported among the inhabitants, although the latter are derived from many parts of Egypt and also include Europeans from India, the Southern Soudan, etc. One might reasonably expect, therefore, that some cases of malaria would occur among such a population and that, in the presence of abundance of supposed carriers (*i.e.*, pharoensis), an outbreak of malaria would occur, but this was not so."

192. The Nile reaches its lowest level in May and begins its seasonal rise in July; and the flood water begins to inundate the country in July and reaches its maximum in September. Thereafter the floods subside, falling below the inundation level in a normal year in November. Except as regards rainfall, conditions in Egypt are in many ways comparable to those existing in much of Eastern Bengal at present, where inundations prevent any considerable breeding of anopheles until late in the season, thus keeping the country free of malaria. A further observation of Mr. Willcocks' supports this view. He states :—

"With regard to the question of the apparent rarity of malaria in the environs of Cairo, one fact must not be lost sight of, namely, that the mosquito invasion takes place late in the year and lasts a short time only."

In the inundated portions of Bengal, it is a matter of common remark that mosquitoes are most frequent after the rains and in the dry season. During the dry season, cases of new infection are rarely met with though relapses are common. Apparently anopheles rarely carry infection during the dry season.

### 107.—Bonification in the Madras Deltas : Tanjore.

193. As in Egypt, so also in the Madras deltas, bonification has been effected by irrigation works. The deltas of the Cauvari (Tanjore) and the Godavari in Madras have both passed through periods marked by agricultural decline, depopulation and epidemic malaria. They have both been restored to health and prosperity by the carrying out of immense irrigation schemes designed in each case by the same officer, the late Sir Arthur Cotton. R. E. In 1809. we learn that, the Cauvari delta was affected with epidemic malaria. In 1827, that "absolute ruin stared Tanjore and the adjoining districts in the face." In 1833, that the need for wide-reaching works was exceptionally great, when Captain Arthur Cotton, R. E., was first sent to inspect the delta, whose population was nearly in a state of rebellion from neglect. In 1836, that "there was no prosperity, when Captain Cotton conceived his plan. On the contrary, the district was in a state of decay, the people spiritless and suffering." Seventeen years later Colonel

Baird Smith, himself one of the greatest irrigation engineers that India has seen, remarked of the same area:

"The permanent prosperity of Tanjore is without doubt to be attributed in a large measure to that first bold step taken by Colonel Cotton in the construction of the upper Coleroon dam."

194. Altogether there are just over 1,000,000 acres of land under irrigation in the delta which has long borne the reputation for being one of the most prosperous areas in the whole of India. In 1878, it was stated:

"The Tanjore works have been the principal means of raising the condition of two and a quarter million people to such a state of wealth and prosperity as we may safely believe no district of India ever attained before."

In 1918 we learn that, among 589,726 out-patients admitted for treatment at dispensaries in the Tanjore district, only 11,237 or 1·9 per cent. were cases of malaria.

### 108.—The Condition of the Godavari Delta in 1842.

195. The case of the Godavari delta is even more striking than that of Tanjore. In 1839, the district was in such a ruinous state and there had been such a fall in land revenue that the East India Company deputed Sir Henry Montgomery, Bart., of the Madras Civil Service, to make minute enquiries on the spot into the general condition of the people. That officer found that much land had gone out of cultivation, largely owing to the neglect of irrigation in the delta. There were but 19,000 acres of the delta imperfectly and irregularly watered from the river, and altogether 69,000 acres wetted from all sources. The population had declined from 738,308 in 1821 to 561,041 in 1842. Under normal circumstances, there should have been an increase of one per cent. per annum, therefore the decrease of population was really equivalent to a loss of over 300,000. The delta was then not only a very poor district but also "a very feverish one." On the recommendation of Sir Henry Montgomery, Major (afterwards Sir) Arthur Cotton was sent to investigate the possibilities of irrigation in the delta. He found that the delta of the Godavari included about 1,700 square miles of country, of which 816,000 acres was cultivable, 272,000 acres being occupied by sandy tracts, channels, roads, village sites, etc.; and he estimated that irrigation might be expected to increase the gross produce

of this area by no less than £ 1,200,000 per annum, land revenue being at the same time increased by £ 20,000. He proposed, including the adjoining Kistna delta in the scheme also, whereby, a much larger area than that stated above would enjoy equal benefit. "If it be asked", he said, "how is this great sum of money to be obtained?" the answer is; "simply by converting the water of the Godavari into money instead of letting it run into the sea."

196. The requirements for an effective system of irrigation for the Godavari delta were stated by Major Cotton to be :—

*1st*—The embankment of the rivers to secure the crops from destruction by the river floods.

*2nd*—Dams, with channels of irrigation leading from the river to bring its water from the level of its bed to that of the surface of the land.

*3rd*—Surplus channels, to lead off the floods caused by the local rains from the flat lands to the sea.

*4th*—Raised roads and bridges, to allow of the conveyance of produce to the markets and to the coast through a country which is otherwise, from its nature, impassable in the rains

He concluded his report with the following words :—

"I have no doubt that a complete system of irrigation here would increase the produce of lands now cultivated by one half, and that, with greatly diminished labour, so that food could be produced at one half the cost that it now is."

### 109.—The Original Aims of the Godavari Project—True "Bonification."

197. The Directors of the East India Company were greatly impressed with Major Cotton's suggestions, as would appear from their letter agreeing to his proposals, which contains the following passage :—

"The investigations of Major Cotton, the Civil Engineer of the Division, as detailed in his able and interesting report of the 17th April 1845, have shown the practicability of turning the waters of that river to the most profitable account by the construction of an anicut of such a height as to command the whole of the delta of the Godavari, and to supply to the rich alluvial soil of which that tract is composed, the means of constant irrigation."

At the same time, they summed up the benefits anticipated from the project under the following heads :—

(1) Laying the foundation for the complete irrigation, for a rice crop, of the whole delta of the Godavari and part of the Kistna, in all three thousand square miles, or nearly two millions of acres.

(2) Providing for leading, out on the land, of every drop of water of the Godavari. in the low freshes, and thus making use of what is now totally lost.

(3) Opening the way for the conversion of the delta from a mere grain district to a sugar plantation.

(4) Thus the produce of this tract, which at present probably does not exceed £300,000, would, when full advantage is taken of the water thus distributed over it, be increased to at least £2,000,000.

(5) This tract, which now pays with great difficulty about £220,000, would then, with great ease, pay £500,000 or £600,000.

(6) A complete system of internal navigation, intersecting the whole delta, would be established throughout the year.

(7) Every village would be furnished with a stream of pure water for the people and cattle at all seasons.

(8) The present estimate provides for the full irrigation of all the tracts at present partially irrigated by the principal channels of the Godavari.

(9) It will give us at once the use of a large portion (about one-third) of the water of the low freshes during the whole summer, thus providing for sugar cultivation to the extent of about thirty thousand acres.

(10) It will give a constant supply of water to those tracts which, like Tanuku taluk, are situated near the present channels, but which receive no benefit from them at all.

(11) It will put a famine in this or the neighbouring districts out of the range of probability.

(12) It will provide immediately two or three most important lines of water communications from Rajahmundry through the heart of the delta to the sea, available at all seasons.

(13) It will have the important effect of showing to the people what can be done for them. At present they have no idea of the water being thrown into the channels during the summer; and from the first moment that water is seen passing through any villages in the low freshes, the whole people of the delta will be awakened to its

great capabilities, and will be prepared to welcome the opening of channels throughout the whole tract, and to extend the cultivation of sugar and other things which are at present limited by the want of water.

(14) It may be estimated to yield £ 10,000 or twenty per cent. on the outlay in the first year, and at least £50,000 or cent. per cent. within ten years. This is much less than the new works in Tanjore yielded under circumstances which did not offer anything like the advantages that the state and capabilities of this district hold out.

(15) But it seems to us that the most important point of all, in the present state of this district, is its capabilities as a a sugar plantation; and the anicut will immediately provide for the most unlimited extension of that culture. When this work is executed, there will not remain a single obstacle to this most valuable plant becoming the main product of this district. Water would be provided for at least three thousand pooties,* producing, with the Indian cane, sugar of the value of £ 130 per pooty, and with Mauritius cane, if we are rightly informed, double that sum, while grain produce is worth only £ 12 per pooty.

### 110.—The Effects of Sonification in the Godavari Delta.

198. As regards the immensely beneficial results of the Godavari irrigation, there is no question. In 1902-03, the net return on the capital cost of the works was 18·4 per cent. Population has vastly increased, the agricultural production is enormous and the whole area now enjoys extraordinary prosperity. In 1879, it was calculated that goods of the value of upwards of £3,500,000 passed over its canals, while the value of the exports and imports of the district which, in 1847 before the construction of the anicut, amounted to £170,000, had risen in 1887 to upwards of £1,500,000. "Taking all things into consideration", says the Hon'ble Alfred Deakin speaking of Godavari in his book on Indian Irrigation, "it may be questioned if there is a more beneficial or more profitable public work in the world. . . . There are three hundred and seventy miles of main canal, of which three hundred and thirty-nine are navigable and eight hundred and forty

* A pooty is 8 acres.

miles of distributaries. The accumulated surplus is over one million pounds, and the gross returns sixteen per cent. on capital. The net revenue for 1888-89 after deducting interest and all charges is £82,269 and the net profit 8·66 per cent. upon the investment." The percentage of net revenue to capital outlay 24 years later, in 1902 was no less than 18·4 per cent. The increase in land revenue alone in 1898 amounted to a 250 per cent. increase over the total revenue from all sources in 1843-44. The figures for total revenue given in Walch's "Godavari" show that the increase in 1894-95 represented a gain of no less than 400 per cent.

199. The following extracts, from various books and reports, dealing with the Godavari delta, serve to throw further light upon the change effected by the irrigation project :—

"At one time it was brought into a state of extreme impoverishment and distress. Since the introduction, however, of the admirable system of irrigation, it has brightened and revived. The people are prosperous and contented. It is the garden of the great Northern Province. The revenue, instead of being reduced as it once was to the verge of bankruptcy, is more elastic than it has ever been, its population has more than doubled, the material prosperity of its inhabitants is proved by their being better fed, better clothed and better educated than formerly, its commerce has flourished and its trade has developed in a marvellous degree. Roads have multiplied; the indigenous schools considerably improved and their number increased; sanitation attended to; tanks and wells dug even in remote places. The number of village schools has so considerably increased that there are now four Deputy Inspectors and one Assistant Inspector for the whole District instead of one Inspector some 7 or 8 years ago. There is besides an Inspecting School master for each taluk."

### 111.—The Effect of Godavari Irrigation on Malaria.

200. Since the completion of the great irrigation project in the delta of the Godavari, malaria has greatly declined and has now become almost a thing of the past. And the same result has been achieved in the neighbouring delta of the Kistna, where a similar irrigation project has been carried to completion with enormous benefit to the people. Europeans and Indians alike bear witness to the extraordinary immunity from malaria now enjoyed by those residing in these two deltas, in spite of the fact that they live surrounded by rice cultivation, which often extends almost up to the doors of the houses. This was not always a characteristic of the Godavari delta. On the contrary, that area once bore an unenviable reputation owing

to the prevalence and severity of malaria. While the irrigation works were still in progress malaria epidemics occurred from time to time and attracted considerable attention. This was especially the case between 1869 and 1873. In 1871, a special medical officer was sent to investigate the outbreaks, which in some quarters had been ascribed to the influence of the irrigation works. A Government Resolution of 1873 seems even to have accepted this view, at least in part, for it states that :—

"The Governor in Council cannot but feel convinced that the deplorable prevalance of fever in this district is mainly due to the cause, as forcibly sketched by Mr. Foster and Mr. Stewart, the utterly inadequate means of drainage in a tract whose swampy nature has been aggravated by the great system of irrigation works."

But this view was not supported by the medical evidence. The Sanitary Commissioner, for example, commenting in his report on the results of the enquiry carried out by Assistant Surgeon Wright in 1871, remarks that, "the results of five years' registration demonstrates in a very clear manner that the intensity of the fever in any taluk has no relation to the extent of irrigation of the land." For our present purpose, these statements afford evidence that the Godavari delta was undoubtedly very malarious at a period not so very remote. Further evidence on this point is also afforded by a statement that appeared in certain Calcutta papers in 1873 to the effect that "the Godavari district in Madras is afflicted with fever of the same type which is decimating the fever tracts of Midnapur, Burdwan, Hooghly and other districts in Bengal."

201. It was not long before the beneficial effects of the irrigation works in reducing malaria began to be apparent. The evidence given before the Public Works Committee by Colonel Fischer, R.E., is very clear on this point and is worth quoting in full.

Col. Fischer, R.E. Public Works Committee. 1878—

*Q*.—Are they (the Godavari works) without any draw back in respect of unhealthiness or exhaustion of the soil or anything of that sort ?

*A*.—There is no exhaustion of the soil; the soil is fertilised from the river every year That is not the thing complained of by the people at all.

*Q.*—Have you observed any unhealthiness attending the irrigation system?

*A.*—We had a very unhealthy season indeed in 1869 from fever, but the doctors are of opinion that it was not due to the irrigation. The population has increased very largely and the people have increased enormously in wealth and comfort.

*Q.*—On the whole you are of opinion that the health of the district has not deteriorated?

*A.*—I should think that the health of the district has considerably improved.

*Q.*—Was the district an unhealthy one before?

*A.*—It was a very feverish one and a very poor one.

*Q.*—And you think there is less fever than there was previously?

*A.*—I believe so.

202. Sir Arthur Cotton held the same views as Colonel Fischer. Writing of the Godavari delta in 1878, he said: "while the delta has very little fever, the moment you go into the upper tracts you encounter it continually." The improvement in the public health conditions, as regards malaria, has steadily continued. And now, as we have seen, malaria is practically a thing of the past. The *Gazetteer* of the Godavari district contains a statement in this connexion, which re-echoes the views of Sir Arthur Cotton. "The fact remains", it says, "that the delta taluks (unlike irrigated areas in some places in this Presidency, the valley of the Tungabhadra, for example) are not greatly subject to malaria, and are, in fact, the part of the district in which it is least prevalent." There is statistical evidence to prove that this is no fancy picture of the conditions relating to malaria. Reference to the Annual Report of the Dispensaries of the Madras Presidency for 1918 shows that among a total of 449,615 out-patients admitted for treatment at dispensaries in the Godavari delta, only 24,954 or 5·5 per cent. were suffering from malaria. This is in striking contrast to the records of fifty years ago when, as we have seen, malaria was so prevalent in the delta as to be made the subject of a special Resolution of Government.

203. Reference has been made to the Kistna delta which adjoins that of the Godavari and like it enjoys the benefits of irrigation. And as in the Godavari delta so also in that of the Kistna, among the blessings bestowed by irrigation,

immunity from serious malaria is not the least At the Simla Malaria Conference of 1909, the Hon'ble Mr. Weir, I.C.S., drew attention to the fact that the Kistna delta was free of malaria in spite of extensive rice cultivation. Judging from the dispensary returns, the Kistna delta exhibits a higher degree of immunity from malaria even than Godavari. In 1918, among 363,107 out-patients treated at dispensaries in the Kistna delta, only 11,257 or 3·1 per cent. were admitted for malaria.

### 112.—Some Existing Schemes of Bonification in Bengal.

204. Bengal is not without examples of bonification. Up to the present, however, most of the projects that have been carried out belong to the drainage type and apply to relatively small areas. The first scheme of this nature to be undertaken was to provide drainage for the Dankuni Jolah, a large swamp in the Hooghly district, with a view of benefiting both health and agriculture. The scheme was completed in 1873, and it was then found that, although originally designed entirely for the drainage of the swamps, actually the irrigation of these swamps was often necessary. In practice, the sluices have been used almost as frequently for irrigation as for drainage and in some years even more for letting in water than for letting it out.

"Experience has proved," says Colonel Haig, R.E., writing of the Dankuni Jolah Project in 1878, "not merely that it is only in so far as irrigation can be combined with drainage that the full benefit of these schemes can be derived, but that for all practical purposes the improvement is limited to the area for which irrigation is available"

Colonel Haig's statement is borne out by the figures quoted regarding the number of days during the five years on which the sluices were opened for drainage and for irrigation respectively :—

**Number of Days on which Dankuni Sluices were opened.**

| | For drainage. | For irrigation. | Rainfall, June to October. |
|---|---|---|---|
| | | | Inches. |
| 1873 ... ... ... | ... | 15 | 34 |
| 1874 ... ... ... | ... | 13 | 41 |
| 1875 ... ... ... | 8 | 15 | 34 |
| 1876 ... ... ... | 8 | 26 | 46 |
| 1877 ... ... ... | 4 | 22 | 38 |

205. "The capacity of the sluices," says Colonel Haig, "is in fact determined, not with reference to the requirements of drainage at all, but to those of irrigation; it must be such as experience shows to be necessary to raise the level of the water in the low grounds with the gradual growth of the plants, and this probably is in excess of what is required for drainage." While there was no doubt at all about the success of the scheme from the point of view of agriculture, opinions have differed in regard to its effect upon health. "It is to be noted", said the Drainage Committees of 1906 of this scheme and very similar projects in the Howrah district, "that these works were undertaken largely in the interest of land reclamation", and in the annual report of the Sanitary Commissioner for 1879. it was observed as regards the Dunkani project that, "with regard to the fever we are in doubt as to the directly beneficial effect the scheme has had on the health of the people, though of its success as a drainage scheme and of the swamps having been converted into a highly cultivated area, there can be no doubt. There has been an improvement in health everywhere, and an examination of Mr. Adley's report shows that there was no extraordinary sickness in or around this *jhil* in 1867 to 1869." On comparing the mortality figures of the Chanditala and Singur *thanas*, which are within the sphere of the scheme, with those of the remainder of the Hooghly district, the Drainage Committee remarked that "these certainly show some advantages in favour of the former." The figures quoted by them show that the mean of the average mortality rates for Chanditala and Singur *thanas* taken together for the periods 1890 to 1899 and 1900 to 1906, respectively, were 29·9 and 29·7 per 1,000 respectively, compared with 39·3 and 38·9 per 1,000, the mean death-rates of the other *thanas* of the Hooghly district during the same period. During the decade 1901 to 1911 the population of Chanditala and Singur *thanas* increased by 14·6 and 12·4 per cent., respectively, the density of population reaching 1,058 per square mile in the former area and 1,553 in the latter.

206. The increase of population in the Hooghly district as a whole during the same period was only 3·9 per cent. Lt.-Col. Fry, I.M.S., in his second report on malaria, points out that Chanditala and Singur *thanas* are now singularly free of malaria, the spleen rate there being exceedingly low. The schemes in Howrah affect 61 villages in Domjur *thana*. This *thana* showed a 10·7 per

cent. increase of population in the decade ending 1911, and the mean density was found to be 2,212 persons to the square mile. The Magistrate of Howrah, writing of the Howrah and Rajapur schemes in 1898, remarks :—

"All the drainage schemes have proved of immense benefit in reclaiming waste swamps and improving the other lands. They were originally intended for the drainage of the swamps, but they are now advantageously utilized in irrigating the lands, in years of drought and scanty rainfall, with fresh water from the Hooghly river." More recent evidence also supports this view. "These schemes," says the Commissioner of the Burdwan Division in 1905, "have proved very successful in reclaiming the extensive swampy lands west of Howrah, and improving other lands. The surplus water is drained out of the channels and sluices in years of heavy rainfall, while in years of drought, water from the river is let in for cultivation and drinking purposes. The schemes have been of great benefit to the people of the neighbouring tracts, who can reap a good harvest in years of drought as well as in years of heavy rainfall."

207. As regards the recent results of the schemes in Hooghly and Howrah, examination of the mortality figures for the five years prior to 1918 shows the following :—

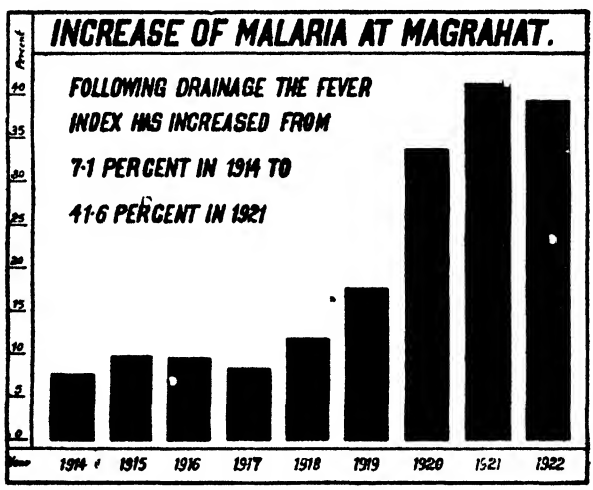
| | Average fever mortality per 1,000 | Average total mortality per 1,000 |
|---|---|---|
| | 1913-17. | 1913-17. |
| Chanditala thana ... ... | 14·2 | 25·6 |
| Singur thana ... ... | 20·2 | 28·0 |
| Hooghly district ... ... | 21·6 | 33·7 |
| Domjur thana ... ... | 10·2 | 24·9 |
| Howrah district ... ... | 10·2 | 26·8 |

The period 1913-17 has been taken in order to avoid the inclusion of the influenza figures which have vitiated the returns in 1918 and 1919. It will be seen from the figures quoted that Chanditala *thana* continues to compare favourably as regards health with the remainder of the Hooghly district. The results in Singur *thana* are not so good. As regards the effect of the works in Howrah it must be remembered that a portion only of the Domjur *thana* is affected by the schemes; and Howrah district itself, with the exception of Jagatballavpur *thana*, is not very malarious.

### 113—The Magrahat Scheme.

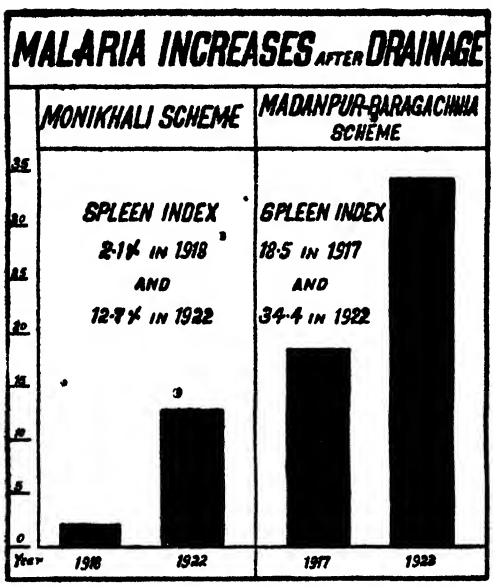
208. An even larger scheme of drainage has been carried out in recent years in the Magrahat *thana* of the Diamond Harbour subdivision of the

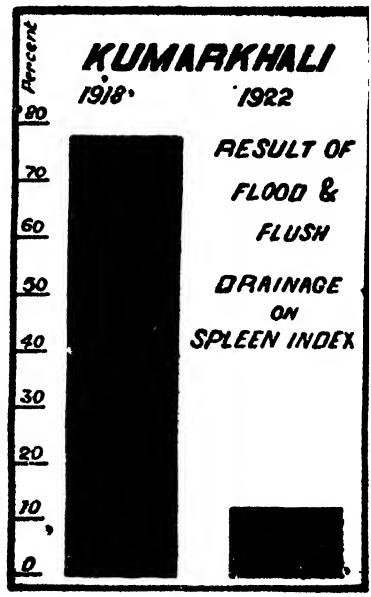
24-Parganas. This scheme, which is known as the Magrahat drainage scheme, affects an area of over 300 square miles. It was completed since 1909. Investigation has shown that the low-lying area included in the scheme was not highly malarious at the time of its inception, although certain higher areas adjoining have long been intensely unhealthy on account of malaria. Unfortunately, the carrying out of the Magrahat drainage scheme has been followed by an immense increase of malaria as may be seen by the attached block which shows that a great rise has taken place in the fever index in recent years. The Census of 1921 also disclosed the fact that since 1911 the population of the area chiefly affected by the scheme has ceased to expand, although other parts of the Diamond Harbour subdivision have shown a simultaneous increase




of population. Had the drainage scheme really produced the improvement it was designed to effect, it is inconceivable that malaria should have increased and population should have ceased to exhibit a healthy growth. As will be seen below, other schemes of drainage have proved to be equally unsuccessful and to have led to similar increases of malaria. A number of other schemes of a similar character have been carried out from time to time in the same part of the 24-Parganas. Up to 1906, a total of 205 square miles was drained in this way. Altogether considerably over 600 square miles have now been provided with gravity drainage, regulated by sluices, which can be used if necessary for irrigation. The latest project of this nature is that of the Manikhali khal area.

a basin of about 16 square miles. Unfortunately these schemes have failed. It has been known for hundreds of years that the draining of swamps involves a grave risk of increasing malaria unless the work is done so thoroughly that the land will either grow dry crops or at least be fit for pasture. On the other hand, ever since Empedocles flooded the lowlands surrounding Selinos and in this way made the city healthy, it has been known that swampy tracts may be freed from malaria by flushing them with an abundant supply of water.




We now have definite proof of these two facts in Bengal, as may be seen by the inserted blocks, above, which show the increase of malaria that has followed drainage in two separate localities and on the other hand, the great diminution of malaria that has occurred at Kumarkhali since the carrying out of a small scheme for the purpose of flushing out the drains, ditches and hollows in and about the town, with an abundant supply of water from the river.

### 114—A Warping Project.

209. Mention must be made of a scheme of another type, namely "warping" or Colmata which has been attempted in the neighbourhood of Berhampur in the Murshidabad district. This scheme appears to have been

designed with a view of silting up a large *jhil*, called the Bistopur Jhil, which once formed part of the bed of the Bhagirathi. but was separated from it when that river short-circuited the loop which now forms the *jhil*. The original proposals were excellent as far as the silting up of the *jhil* was concerned, but they were considerably modified before being carried into execution in 1909, with the result that it is not likely that they will ever achieve the purpose intended. Besides this, it is doubtful if the end aimed at, viz., the silting up of a lake of deep clear water would result in any improvement in the health of the locality. On the contrary, it is much more likely to render it unhealthy. Observations made a few years back on the prevalence of malaria around the *jhil* showed that infection was far less prevalent where the water was deep than near the portion where it has been made shallow by the silting operations. As it will take very many years before the character of the *jhil* can be changed from that of a fishery preserve to that of a rice field, and as during the intervening period the operations are much more likely to increase than to diminish malaria, this scheme does not deserve to be called a measure of bonification.

### 115—Resuscitation of Dead Rivers.

210. For many years there has been an insistent demand for measures to improve the silted up channels and resuscitate the dying rivers and khals that are to be met with throughout the decadent deltaic tracts. As far back as 1868, the Sanitary Commissioner remarked in his report that the history of Bengal in a sanitary point of view is the history of its rivers and water-courses. Everywhere the cry is, restore the rivers, re-excavate the channels and open up their off-takes from the Ganges or other main stream, as the case may be. The dwellers in the delta tracts seem to know instinctively that their well-being depends upon the restoration of the river system. In answer to an appeal from the people asking that water which had been shut out by the construction of the Damudar embankment, might be restored to the old channels, the then Lieutenant-Governor, Sir George Campbell, acceded to their request and ordered the carrying out of arrangements by which water from the Damudar could be admitted into the Kana Nadi. Later on more permanent arrangements were made at the instance of Sir Ashley Eden that led eventually to the construction of the Eden

Canal system, which now serves some 36 square miles in the Hooghly district. The letting in of flood water from the Damudar into the Kana Nadi and other decadent channels had a remarkable effect in improving the health of the areas which they served. "The admission of Damudar water," says Dr. Coats, the Sanitary Commissioner, "into the Kana Nadi in 1873-74 and 1875 was followed by an immediate and marked amelioration in health." This view was corroborated by other observers also. "The letting in of the Damudar water," wrote Dr. Dutt of Serampur in 1879, "was a most welcome relief and that, but for it, parts of the country would have been entirely depopulated . . . It has been allowed to flow in 1878 and 1879, and the people say that the epidemic has disappeared since the last two years. These facts leave no doubt that the letting in of the Damudar water into the Kana Nadi and through it into the khals, drains, tanks, etc., in the interior of the subdivision, has led to this improvement." In a further report on the effect of the measure Dr. Coats specially recorded the great benefit derived from this flushing of the Kana Nadi. "At a recent visit," he says, "I myself found only 2 per cent. of the people suffering from enlarged spleen and anaemia. The *pathshalas* were full of healthy boys, not one of whom had splenic enlargement, cultivation was going on actively and people were eager to have increased water-supply and drainage."

### 116—The Demand for Water.

211. The demand for increased water-supply is common to every one of the malarious deltaic areas. "The prevalence of fever," says the Deputy Magistrate of Chuadanga in 1884, "appeared to be due to deficient water-supply." And this remark only echoed the earlier report of the Nadia Fever Commission of 1881, which states :—

"In fact, as Dr. Sutherland observed in 1868, the district is becoming more and more arid, tanks and other reservoirs of water dry up even before the hot season, tanks full to overflowing in the rains rapidly dry up — facts which prove that there has been no increase or excess of moisture in the soil. The very jungle, contrary to the assertions of some natives we met, as Dr. Lidderdale points out, is of a kind which prefers a dry to a damp habitat."

212. More recently, Babu Bhola Nath Banarji, Executive Engineer, in charge of the Special Drainage Division, who

has been investigating conditions in Jessore, states in his report of September 1912 :—

"If you draw a line from Pultia on the Ichamatty to Jhiker,gacha on the Kabadak, the country lying to the north of this line may be generally taken as suffering from scarcity of good drinking water. . . . This is due to the silting of this part of the country by action of deltaic rivers. . . . There are no big sized tanks in most of the villages, and people have to travel a long distance to the nearest river or *bil* for their supply of drinking water. It is reported that tanks in those parts do not hold water, but dry up with the subsidence of the rivers, and are consequently too expensive to be excavated below the subsoil water level. It will not be out of place if we note the fact that the tracts, away from the river and also places which complain of scarcity of water and where *bils* and pits dry up much earlier, are not free from malaria, as it ought to be, if dampness alone was the cause of malaria. Most of the Jhenida subdivision and parts of the Magura subdivision, where people suffer from want of water and which are away from the big rivers and high lands, constitute the most malarious parts of the district."

The formation of the Special Drainage Division for the Presidency Division was the outcome of the recommendations of the Drainage Committee of 1906. A large amount of survey work has been carried out by this division. Lord Carmichael during his incumbency as Governor took special interest in the investigation of malaria, but owing to the occurrence of the great war he was not able to see the maturing of any large scheme for the amelioration of the disease.

### 117—Recent Activity in connexion with Anti-malarial Projects.

213. When His Excellency Lord Ronaldshay assumed charge as Governor of Bengal. he at once turned his attention to the problem of malaria. As a result, a distinguished officer of the Irrigation Department was put on special duty for the express purpose of dealing with this question in collaboration with the Sanitary Department. Within a comparatively short period many proposals were investigated and a considerable number actually carried into operation. These various schemes comprised both drainage projects and schemes for the restoration of decadent rivers. Among the former were the Manikhali basin project, previously mentioned, the Arool Bil project, the Ampta drainage project, the Baragachia project, the Chapra Bil project ; and among the latter were the re-excavation of

the Saraswati channel, the improvement of the Jamuna river, the improvement of the Nawai and Sunthai rivers and the Bhairab river project. Besides this, four special experimental anti-malarial schemes, already mentioned elsewhere, have been carried to fruition during the past four years. Of these four schemes, one may be claimed as an example on a small scale of the principles of bonification, since agricultural improvement has been secured at the same time and by the same means that are being employed for the amelioration of malaria. This small scheme, "the Banka valley scheme", depends upon partial flood irrigation controlled by sluices and regulators from the Banka river, an off-shoot of the Damudar. From four to six square miles of country are affected. As previously recorded, in paragraph 158 of this report, the project when only partially complete was responsible for the saving of the crops in the area served, which would otherwise have been destroyed by floods. Particulars as to the effect upon health during 1923 have just been received, and show that the spleen index has decreased in 7 out of 11 villages and the malaria death-rate has also shown a decline.

214. In spite, however, of the greatly increased activity of the past four years, only the fringe of the malaria problem has, as yet, been touched. As this report will show, evidence has been accumulating which points to the necessity of approaching the whole question of the amelioration of malaria in the delta tracts from a much broader standpoint than has yet been adopted; and which suggests that we must look to large irrigation projects and the increased supply as well as the regulation of surface water for the final solution of the problem of Bengal malaria. Meanwhile, the work so far accomplished has served a useful purpose, and has been of the greatest value because it has proved that ordinary drainage schemes are harmful and that what is required is more abundant water and the restoration of flood, and rather than the drying up of the country. Quite apart also from what has actually been achieved, the data that has been collected will prove of immense service later on in the preparation of the irrigation projects that will have to be undertaken. All projects of this kind require the most careful preparation necessitating a detailed survey of the areas to be dealt with. The records in connection with the work already accomplished will, it is hoped, supply much of the necessary information and thus shorten very materially the period required for the preparation of new projects.

### 118—The Contrast between the Madras and the Bengal Deltas.

215. In spite of what has been already done in the way of bonification, the malaria-stricken deltas in Bengal exhibit a sad contrast to the irrigated deltas of the Godavari, the Kistna and the Cauvari in Madras. The fever index of Western Bengal is 10 times as high as that of Godavari, 18 times that of Kistna and 29 times that of Tanjore; the fever index of Central Bengal is 8 times that of Godavari, 14 times that of Kistna, and 23 times that of Tanjore; the fever index of Northern Bengal is 5 times that of Godavari, 10 times that of Kistna and 15 times that of Tanjore: and even Eastern Bengal which is the healthiest part of Bengal has a fever index more than $2\frac{1}{2}$ times higher than that of Godavari, 4 times that of Kistna and 6 times that of Tanjore. "These fevers are actually owing to want of irrigation works". said Sir Arthur Cotton over forty years ago, of the epidemic malaria then raging in Halishahar and other parts of Bengal. And in view of many of the facts that have now been brought forward, one is constrained to accept his view that "if the waters were regulated, the country properly drained, and streams of fresh river water were flowing through every village throughout the year, the fever would be almost entirely subdued as it is in Godavari and Tanjore." The possibilities of applying bonification by irrigation for the purpose of ameliorating the malaria of the deltaic areas in Bengal will be considered in a later chapter. And before discussing this question, an attempt must be made to explain the manner in which the principles of bonification can be utilized for the suppression of malaria. This is the more necessary because the special form of bonification proposed for Bengal is irrigation; and as is well-known, there is a widely current opinion that far from reducing malaria, irrigation has often proved to be a very serious factor in the spread of the disease.

### 119—How Bonification influences Malaria.

216. Bonification causes a reduction of malaria by the interaction of the following factors :—

(1) Reduction in the numbers of the local anopheline carriers of malaria.

(2) Increase in the number of the local human population.

(3) Increase in the prosperity of the local human population.

At the moment it is unnecessary to discuss the relative importance of these three factors, and it is doubtful if the data available is sufficient to enable us to come to a decision on this point. All that need be stated for our present purpose is that there are grounds for believing that each of the three factors named exerts a favourable influence upon malaria ; and that, when these favourable influences are all acting together, the cumulative effect upon malaria is so great as to cause a very marked reduction in the prevalence of the disease.

### 120—Effect of Reduction of Anopheles on Malaria Prevalence.

217. It is now universally admitted that a reduction in the number of anopheline carriers of malaria reduces the spread of malarial infection. Ross has pointed out that a complete reduction of anopheles is not essential to the eradication of malaria. "Malaria", he says, "may be completely reduced even by a partial reduction of the anophelines below the necessary limit (which I have roughly estimated to be about 40 different anophelines per head per month) and it may be partially reduced even by a smaller reduction of the insects."

218. Let us try and get a clearer idea of what this proposition may actually mean in practice. Accepting certain of Ross's mathematical assumptions for this purpose, let us assume that we have to deal with a square mile of malarious country inhabited by 1,000 people, both the human and the anopheline population being evenly distributed throughout the area. What would be the effect of permanently reducing the number, or in other words the relative density, of the anopheles mosquitoes ? The reduction might conceivably be effected either by obliterating the breeding places or by keeping a permanent staff at work destroying their larvæ, as was done in Panama. Suppose the initial infection rate is very high, so that 999 out of the 1,000 people are infected with malaria. In this case, even very thorough anti-mosquito measures will

fail to effect an appreciable reduction in the number of malarial infections, as the following figures will show :—

*Reduction of malarial infections in population of 1,000 following reductions in the proportions of anopheles mosquitoes.*

| Original number of malaria infections in 1,000 people in 1 square mile. | Number of infections after anopheles are reduced by 25 per cent. | Number of infections after anopheles are reduced by 50 per cent | Number of infections after anopheles are reduced by 75 per cent. | Number of infections after anopheles are reduced by 90 per cent. |
|---|---|---|---|---|
| 999 | 998 | 998 | 996 | 990 |
| 990 | 986 | 980 | 960 | 900 |

Now, while it is often an easy matter to reduce anopheles by 25 per cent., and not very difficult to diminish them by 50 per cent., a 75 per cent. reduction is not so easily effected, and to reduce them by 90 per cent. means very careful and thorough work indeed. But the figures given show that even a 90 per cent. reduction of anopheles would not necessarily produce any appreciable effect upon the prevalence of malaria in severely infected areas. The term "appreciable" is used advisably, because existing methods of measuring the malarial infection rates of a community are at present inadequate for clearly demonstrating such small differences in actual infection rates as those between 99·9 and 99·0 per cent. or even between 99 per cent. and 90 per cent. But there is another reason why even a 90 per cent. reduction of the anopheles breeding within one square mile cannot possibly produce much effect upon malaria, if the initial amount of infection is very great ; and this is the effect of migration of anopheles from outside the treated area. In regions of intense malaria, it is not enough, merely to abolish all breeding places within a square mile if we wish to protect the people dwelling within that area.

219. Professors Karl Pearson and Dr. Blakeman have made some exact estimates in this connexion on data supplied by Sir Ronald Ross ; and their conclusions respecting the density of the anopheline population in one square mile of country, surrounded by areas in which anopheles mosquitoes are breeding (but, as far as the one square mile itself is concerned, absolutely sterile of breeding places), are briefly as follows :—

"In a sterile square mile the density should be 50 per cent. at the boundary, 11 per cent. half way to the centre

and 2 per cent. at the centre." Now 2 per cent. of 40,000 and 4,000, the numbers of anopheles per head required to produce infection rates of 99·9 and 99·0 per cent., respectively, is 800 and 80, respectively; and 11 per cent. is 4,400 and 440, respectively. So that, even if we abolished all anopheles breeding places within our one square mile, migration from without would still supply enough anopheles to keep the rate of infection at over 99 per cent. ¼ mile from the boundary and 95 per cent. at the exact centre in the one case, and 91 per cent. at ¼ mile from the boundary and 60 per cent. at the centre in the other. In the circumstances stated, therefore, although very thorough and expensive measures may be adopted, they may appear in practice to be absolute failures. And this explains why quite a number of schemes, in very malarious parts of India, have been looked upon as failures. Now let us now glance for a moment at the other side of the picture. Suppose that, instead of having 999 or 990 infected persons among the 1,000 in our square mile, only 500 are infected at the beginning, what will be the final result of anti-mosquito measures producing similar reductions, viz., 25 per cent., 50 per cent., 75 per cent. and 90 per cent. in the proportions of anopheline mosquitoes present?

*Reduction of malarial infections in a population of 1,000 in one square mile following upon a permanent reduction in the proportions of anopheles mosquitoes present.*

| Original number of infections | Number of infectious after anopheles are reduced by 25 per cent. | Number of infections after anopheles are reduced by 50 per cent. | Number of infections after anopheles are reduced by 75 per cent | Number of infections after anopheles are reduced by 90 per cent |
|---|---|---|---|---|
| 500 | 333 | 0 | 0 | 0 |

220. In these circumstances, we see that a very substantial fall in the number of malarial infections would follow a relatively small reduction of anopheles mosquitoes, viz., 25 per cent., and that the disease would tend to die out completely if the anopheles mosquitoes are reduced by only one-half. When the initial rate of infection among our 1,000 people is lower than 50 per cent., the results would be even

more successful and dramatic, as may be seen by the figures given below :—

*Reduction of malarial infection rate in a population of 1,000 following upon reduction of anopheles.*

| Original number of infections in population of 1,000. | Final number of infections remaining after permanent reduction of anopheles by 25 per cent |
|---|---|
| 200 | 0 |

This explains the success of the measures at Ismailia.

221. These conceptions are very interesting and also very important both when considering the application of anti-mosquito measures in practice and for understanding the manner in which bonification can bring about a reduction of malaria. In the first case, they enable us to grasp the fact that anti-mosquito measures have their limitation ; that in certain places they can be applied with the certainty of producing excellent results, whereas in other circumstances they may appear practically useless ; and in the second case, they help to explain how irrigation and other measures of bonification that, although primarily aimed at improving agriculture, may also reduce the breeding of anopheles to a considerable extent, will be able to produce a great diminution of malaria. The table below shows the possible results of mosquito reduction in areas with different initial rates of infection .—

*Reduction of malarial infections in a population of 1,000 following a reduction in the number of anopheles mosquitoes.*

| Original ratio of malarial infections per 1,000 | Number of infections finally remaining after anopheles are reduced by 25 per cent | Number of infections finally remaining after anopheles are reduced by 50 per cent. | Number of infections finally remaining after anopheles are reduced by 75 per cent | Number of infections finally remaining after anopheles are reduced by 90 per cent |
|---|---|---|---|---|
| 999 | 998 | 998 | 996 | 990 |
| 990 | 986 | 980 | 960 | 900 |
| 900 | 866 | 800 | 600 | 0* |
| 800 | 733 | 600 | 200 | 0 |
| 700 | 600 | 400 | 0 | 0 |
| 600 | 466 | 200 | 0 | 0 |
| 500 | 333 | 0 | 0 | 0 |
| 400 | 200 | 0 | 0 | 0 |
| 300 | 47 | 0 | 0 | 0 |
| 200 | 0 | 0 | 0 | 0 |

* In this case, the migration factor will keep the infection ratio at the boundary at 80 per cent. and nearly 20 per cent. ½ mile from the boundary.

### 121.—Effect of Increase of Human Population on Malaria.

222. Every one may not at first sight be prepared to admit that an increase of population can by itself have any effect upon malaria. But this question has also been considered by Sir Ronald Ross, who has expressed his views in the following words :—

"Suppose that in a locality the mosquito population remains the same, but that the human population varies ; what will be the effect of this variation on the malaria ratio ? By the static formula* $M = 1 - 40\,A$ ; but $A$ is the number of anophelines, not in unit of space, but per unit of human population. If, therefore, the latter is doubled while the total mosquito population remains constant, $A$ will be halved ; and so on. Thus the static malaria ratio tends to decrease with increase of the density of the human population. That is, other things being equal and the anophelines being supposed to breed equally everywhere, the malaria ratio should be higher amongst a scattered rural population than in a dense urban one, because, evidently the number of anophelines *per* person will be less in the latter. . . . ."

'It may happen that when the human population begins to increase the local breeding surface is already yielding its maximum output of mosquitoes In this case the increase of the human population should cause a decrease in the static malaria ratio."*

223. Let us assume once more that we have a square mile of malarious country in which there are 1,000 people and that both the human and anopheles populations are evenly distributed, what would be the effect on the prevalence of malaria of introducing a number of other individuals and thus increasing the human population ? We may assume for our purpose, using Ross's invaluable mathematical assumptions once more, that the anopheles mosquito population would be as follows, for each of the different ratios of malaria prevalence :—

| Original number of anopheles per head. | Total number of anopheles in one square mile. | Resulting percentage of malarial infections. | Number of malarial infections in 1,000 population. | Number of anopheles per head after doubling human population. | Final number of malarial infections in 2,000 population. | Resulting percentage of infections. |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| | | Per cent. | | | | Per cent. |
| 40,000 | 40,000,000 | 99·9 | 999 | 20,000 | 1,996 | 99·8 |
| 4,000 | 4,000,000 | 99 0 | 990 | 2.000 | 1,960 | 98·0 |
| 400 | 400,000 | 90·0 | 900 | 200 | 1,600 | 80 0 |

* Any reader, who wishes to pursue this subject, must refer to Ross's Prevention of Malaria, 1910 (John Murray).

| Original number of anopheles per head | Total number of anopheles in one square mile. | Resulting percentage of malarial infections. | Number of malarial infections in 1,000 population. | Number of anopheles per head after doubling human population | Final number of malarial infections in 2,000 population | Resulting percentage of infections. |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 200 | 200 000 | 80 0 | 800 | 100 | 1,200 | 6 00 |
| 134 | 134,000 | 70 0 | 700 | 67 | 800 | 40 0 |
| 100 | 100,000 | 60 0 | 600 | 50 | 400 | 20·0 |
| 80 | 80 000 | 50 0 | 500 | 40 | Nil | Nil |
| 67 | 67,000 | 40·0 | 400 | 34 | Nil | Nil |
| 57 | 57,000 | 30 0 | 300 | 28 | Nil | Nil |
| 50 | 50,000 | 20 0 | 200 | 25 | Nil | Nil |
| 40 | 40,000 | Malaria just present perhaps but not able to increase | | 20 | Nil | Nil |

224. If anything happens to bring about an increase of the human population in our square mile of malarious country, while the anopheles population remains unchanged, the proportion of anopheles per head of the human population would obviously be reduced. On the basis of Ross's assumption, this reduction in the number of anopheles available per head, would be followed by a reduction in the *ratio* of malarial infections. A careful distinction must be made between the *ratio* of infections and the *total number* of infections. Doubling the population of a place, that is intensely malarious, may actually increase the total number of infections while reducing the *ratio* of infections. For example, if in our square mile 999 of 1,000 persons are infected the mere raising of the density of the human population to 2,000 would tend to increase the number of infections to a total of 1,996 while the *ratio* of infections would fall by 0·1 per cent. Similarly, when 990 out of the original 1,000 were infected, doubling the density of the human population would reduce the *ratio* of infections by 1 per cent., while the actual number of infections would tend to rise from 990 in 1,000 to 1,960 in 2,000. But in less

malarious conditions, the results of an increase of population would be far more favourable. For example, if only 600 of the 1,000 people in our one square mile were originally infected, by increasing the density of the human population to 2,000 not only would the *ratio* of infections eventually fall from 60 to 20 per cent., but the total malarial infections would tend to fall also to 400, which would mean a decline of 200. If only 500 of our original 1,000 people were infected even better results would follow the increase in density of the population. In this case doubling the human population might so reduce the chances of infection that malaria would tend to become progressively less and less and eventually die out completely. These conceptions help us to understand what happens when a new and prosperous industry is established in a malarious area. It is a matter of common observation that in these circumstances malaria often diminishes though no special measures are taken against the disease. The result is often so marked that people imagine that some beneficient change has occurred in the climate, and in the old days they ascribed this change to some quality in the air or the water of the locality. Changes of this kind have occurred in the case of many of the riparian municipalities near Calcutta since the jute mills and other industries were established there. Many of these towns became intensely malarious after the construction of the railway and the decay of their local industries. The effect of this latter cause in increasing malaria is important, and was first pointed out by Rai Bahadur Dr. Gopal Chandra Chattarji. But just as the decay of one industry may increase malaria, so also the rise in importance of another industry may play its part in reducing malaria. The case of Naihati and Kanchrapara are good examples and afford striking contrasts to Halishahar, which adjoins them. Naihati and Kanchrapara are progressive on account of the local jute mills and the Railway Workshops, respectively and are now healthy and free from serious malaria ; while Halishahar is decadent and intensely malarious. Of course, the improvement that has occurred in Naihati and Kanchrapara is largely due to the money that has been spent on better housing and sanitation generally. But here again the influence of the *prosperity factor* may be perceived, for both the towns mentioned can afford to improve their condition because they are prosperous and progressive ; Halishahar, on the other hand, has no money to do anything and unless her economic condition changes and something happens to attract and

keep population there, no reduction of malaria is probable. Recently the case of Panihati aroused some interest owing to the fact that exception was taken to the establishment of certain industries there. Those who opposed this change did not of course realise that the establishment of industries that would bring prosperity to Panihati would help very greatly to diminish malaria, and might reasonably be claimed as an anti-malarial measure. From this latter point of view, the industrial development of the province and the establishment of new and promising industries may be considered as admirable measures for the amélioration of malaria.

225. The converse holds true also. The decline of once prosperous industries may result in a great increase of malaria. In parts of Bengal where the silk industry is undergoing decline, this factor of industrial decay may be seen in operation. The author has visited village communities in both Birbhum and Murshidabad districts where the closing of silk filatures has undoubtedly led to outbreaks of epidemic malaria among the local population. Of course, malarial infection was already present among the people but the economic stress resulting from the closing down of the industry on which many of them depended for their livelihood precipitated an epidemic of malaria among them which killed many people. Cultivators were affected as well as the actual mill employees because many of the former class depended for a large part of their income on the supply of the mulberry leaves required by the silk worms. The cases that have been mentioned suggest the possibility of using, as a flank attack on malaria, many measures as yet undreamed of by the ordinary sanitarian. For example, an import duty on silk, which would have the effect of restoring the silk industry to its former once flourishing condition would lead to an increase in the prosperity and the numbers of the local population in the old silk producing areas and might thus with good reason be claimed as a valuable measure of relief for the malaria from which these areas have long been suffering. The establishment of important industries may have a very marked effect upon malaria wherever the initial infection rate is below 50 or 60 per cent. In places that are more malarious than this, it must be remembered that any increase in population is likely at first to cause an actual increase in the number of malarial infections, and that unless the population can be tripled or quadrupled very rapidly the economic loss through sickness may easily

cause the abandonment of the locality as the site of a new industry. The table below summarises the results that may be expected to follow when the original 1,000 people in our hypothetical square mile is increased to 2,000, thus doubling the density of the population.

**Effect of Increase of Population on Malaria in one square mile.**

| Initial infection rate per 1,000. | Total infections in 1,000. | Ratio of infections tending to occur after population is increased to 2,000. | Total infections in 2,000 finally. | Increase or decrease of infections. |
|---|---|---|---|---|
| Per cent. | | Per cent. | | |
| 99·9 | 999 | 99·8 | 1,996 | +995 |
| 99·0 | 990 | 98·0 | 1,960 | +950 |
| 90·0 | 900 | 80·0 | 1,600 | +700 |
| 80·0 | 800 | 60·0 | 1,200 | +400 |
| 70·0 | 700 | 40·0 | 800 | +100 |
| 60·0 | 600 | 20·0 | 400 | -200 |
| 50·0 | 500 | 0·0 | 0 | -500 |
| 40·0 | 400 | 0·0 | 0 | -400 |
| 30·0 | 300 | 0·0 | 0 | -300 |
| 20·0 | 200 | 0·0 | 0 | -200 |

It will be seen that the critical point is reached at an infection rate of 60 per cent. Above that any increase of population increases the total number of infections while at this figure itself and below it, any increase of population diminishes malaria.

### 122—The Effect on Malaria of Reduction of Anopheles and a Simultaneous Increase of Population.

226. It has been shown that the reduction of anophelines will in certain circumstances greatly lessen the prevalence of malaria and that the increase of population may have a similar effect. This being so, a very marked reduction of malaria may be expected when both these factors are in operation simultaneously. Here again we are greatly indebted to Ross for a most hopeful and promising conception. According to him, "if the mosquito population diminishes as the human population increases, the malaria ratio should fall greatly."

227. When 60 per cent. of the population of our hypothetical square mile is infected with malaria, diminishing the anopheles mosquitoes by one half reduces the ratio of infections to 20 per cent. If, however, this diminution of anopheles is accompanied by an increase of 25 per cent. in the human population, the malaria ratio will tend to fall to *zero*, and malaria will gradually die out. This is the sort of favourable result to be anticipated from bonification projects. The final elimination of malaria will, however, take some years to accomplish, and it can be greatly hastened by the proper use of specific anti-malarial measures. These measures will be specially called for to expel malaria finally from areas in which the disease may continue to linger in spite of a marked diminution. For example, if the initial infection rate of an area was 80 per cent., the effect of reducing the anopheles by 50 per cent. and simultaneously doubling the human population would cause the malaria ratio to fall to 20 per cent. We should still have 400 infections to deal with among our 2,000 population in place of the original 800 cases of infection. A further permanent reduction of anopheles by 25 per cent. would in these circumstances cause malaria eventually to die out. Measures of bonification can be designed to reduce anopheles and cause a simultaneous increase in agricultural production, thus stimulating the growth of human population. Even if malaria is not entirely abolished by this measure, malaria will decline very greatly, and there will come a time when direct measures of anti-malarial sanitation, either by quinine treatment or anti-mosquito methods, can be applied with absolute certainty of success. Malthus pointed out many years ago that, in favourable circumstances, a population will increase by as much as 25 per cent. in 10 years. We have examples also in Bengal, where a population has actually increased by as much as 50 and even 80 per cent., within a decade, and in prosperous deltaic areas, such as Egypt, increases of 15 or 16 per cent. in 10 years are quite common. After the irrigation system was introduced, the populations of Tanjore and Godavari doubled themselves within a short period. This being so, the factor of population must be carefully considered when dealing with the question of malaria in Bengal. If once we can check the decline of population in the present decadent areas and can establish in place of it a healthy increase of 1·0 to 1·5 per cent. per annum, our great flank attack on malaria will have succeeded; and we can then rest assured that malaria is

beginning to retreat, and will finally be driven from the country.

### 123.—Effect of Increased Prosperity on Malaria.

228. As regards the influence of the third factor, no one will dispute the good effect that increased prosperity exerts in reducing both the prevalence and the evil results of malaria. Increase the prosperity of a community and at once you enable both the individual members and the community, as a whole, to take more efficient action against malaria. The resistance of the individual to disease is greatly strengthened by good and ample food, better clothing and improved shelter; remedies such as quinine can be used in adequate amount by a prosperous population who can also afford to employ skilled doctors. Special personal preventive measures, such as the uae of mosquito nets, also become possible; and profiting by the education which is now within their reach, the members of a prosperous community can adopt measures for improving the sanitary condition of their villages in a manner which poverty had previously placed absolutely beyond their reach.

### 124.—Bonification diminishes Anopheles and Increases Population and Prosperity.

229. The manner in which bonification diminishes anopheles and leads to an increase both of population and prosperity must now briefly be considered. In the opening portion of this chapter (paragraph 166), it was shown that bonification consists in :—

(1) the regulation of all surface waters.
(2) the improvement of the fertility of the soil,
(3) the cultivation of those classes of crops best suited to the local conditions, and
(4) the promotion both of the increase and the prosperity of the resident agricultural population.

What is the action of these various factors likely to be on anopheles mosquitoes, on the density of the human population and the prosperity of that population respectively? The regulation of surface waters is likely to have a two-fold effect; it tends both to reduce the breeding of anopheles and to stimulate cultivation, and it may therefore influence malaria in two different directions, firstly, by its effect upon the insect carrier and secondly, by its influence on the human host.

230. Soil fertility can be improved in many ways :—

(*a*) by irrigation,
(*b*) by silt deposit,
(*c*) by sub-soil drainage,
(*d*) by the use of manures, and
(*e*) by improved methods of tillage, etc.

Certain of these methods of increasing fertility have also a two-fold influence upon malaria. Irrigation may either diminish or increase the breeding of anopheles. Basin irrigation and the system of flush irrigation employed in the Madras deltas are both probably unfavourable to anopheles. But the system of perennial irrigation adopted in many areas, where *rabi* crops are of importance, necessitates vast numbers of canals and distributary channels which hold up rain-water in the monsoon and probably lead to an enormous multiplication of anopheles.

231. The effect of silt-laden water is almost wholly beneficial. Silt-laden water appears to be unfavourable to the larvæ of anopheles mosquitoes and it also tends to destroy aquatic vegetation which would otherwise afford them shelter. Its value as a manure is also generally admitted. The fertilization of soil by silt deposit ordinarily necessitates some form of irrigation. Sub-soil drainage may influence malaria by drying up small surface pools and preventing seepage, thus diminishing the breeding of anopheles and on the other hand by allowing for the proper aeration of the soil it tends to improve the yield of certain crops very greatly and in this way stimulates cultivation and may thus increase the prosperity of the agricultural population, provided conditions of land. tenure, etc., allow of this. There is no reason to suppose that the use of manure can influence malaria except in an indirect manner, either by its effect on cultivation or on the prosperity of the population. Improved methods of tillage may, on the other hand, help to reduce the breeding of anopheles, especially in the case of wet cultivation, and may thus influence malaria both directly through the insect carrier and indirectly through the human host.

### 125.—Effect of Choice of Crop on Malaria.

232. The choice of the crop to be cultivated may have a considerable influence on malaria, both by its effect upon anopheles and through its bearing upon the density of the population. Recent investigations have shown for example

that, rice cultivation, far from causing an increase of malaria, may in certain circumstances lead to a marked reduction. Dr. Butler, M.B., F.L.S., Imperial Mycologist to the Agricultural Department with the Government of India, in a note on the cultivation of rice in Spain and the International Rice Conference at Valencia, refers to an interesting paper on Rice Cultivation and Malaria, read before the Conference by Senor I. G. Colmenares, Regional Health Inspector. In this note, it was stated that the ultimate effect of rice cultivation has been the amelioration of malaria over large areas, especially in so far as the severer types of the disease are concerned. "In these circumstances", says Dr. Butler, "the cultivation of rice becomes a valuable method of sanitary improvement, and should be encouraged by the State . . . . . Properly carried on (in the words of a very competent expert), rice cultivation might be indulged in without danger at the very door of the church." After discussion of the paper, the conclusions regarding rice cultivation unanimously adopted by the Conference were—

"(1) That the cultivation of rice modifies land subject to malaria in the direction of making it more healthy."

"(2) It is advisable to facilitate the making more healthy of obviously marshy lands, even when they are found at a less distance than that authorised by the law."

NOTE.—The Spanish law respecting rice cultivation prescribes among other restrictions that rice fields should be at least 1,500 metres from any inhabited spot, should command sufficient water for irrigation and should be surrounded by a ditch or canal.

### 126.—Increase of Population and of Prosperity.

233. The fourth condition to be fulfilled by any successful scheme of bonification relates to the increase of the population and the improvement of their economic condition. This factor influences malaria indirectly chiefly through its effect upon the human host, and directly, as we have seen in paragraph 222, by reducing the chance spread of infection. The choice of crops has an important bearing on the density of population and its relative prosperity, and may thus influence malaria indirectly through its reaction on the human host. Rice cultivation has long been known to be capable of supporting a denser agricultural population than any other crop. In the same way, valuable crops like jute and sugar cane add very greatly to the resources of a population. These crops require a copious supply of water and must be irrigated in some way,

and they are also specially suited for delta tracts. The intensive cultivation of rice, jute and sugar cane should therefore be encouraged with a view of increasing population and prosperity and so reducing malaria.

### 127.—Possible Causes of Failure in Bonification.

234 Any scheme, designed as a measure of bonification, may fail to achieve its primary object, namely, the reduction of malaria, if it does not fulfil the three conditions that have been explained in the foregoing paragraphs. For example, a system of irrigation which is improperly designed or wrongly worked may lead to a great increase of anopheles mosquitoes and thus cause an extension of malaria. Similarly, a faulty system of irrigation may cause water-logging of the soil and bring about a loss of fertility owing to the raising of the sub-soil water level. In some areas, saline efflorescence occurs as a secondary effect of water-logging and causes a decline of agriculture, resulting in land going out of cultivation. In these circumstances, if malaria is present, it is certain to increase, owing to the decline of population that follows and the accompanying economic stress that occurs among those who remain. Choice of unsuitable crops may lead in certain circumstances to an increase of anopheles and a corresponding increase of malaria. Rice cultivation, for example, when carried out on a small scale, and with a scanty supply of water may be highly productive of malaria. Instances of this kind may be met with frequently in undulating country and may be seen both in the Raniganj coal field, the Madhupur jungle tracts, and certain other areas. A careful distinction must always be made, therefore, between the small patchy type of rice field, which is usually dangerous, and the wide expanse of rice swamp, which is not.

Schemes of agricultural improvement, which do not lead to an increase in the density of the population residing in the areas affected, and which do not increase the material prosperity of that population, will almost certainly fail to produce a decline in the prevalence of malaria.

### 128.—Failure of Certain Schemes in Italy.

235. The recent history of "Bonificazione" in Italy affords many examples of the apparent failure of this measure. It has long been recognized that many of the schemes carried out in later years have not been as successful in mitigating malaria as those of an earlier

period. Celli speaks in 1910 of "36 companies for hydraulic reclamation and drainage, whose work in the Rorigo district has resulted in a greater increase in the value of private property than of amelioration of paludic and malarial conditions." Among these, he names the operations of the Isolad Ariano Hydraulic Company in Punta, where in 1908-09, subsequent to reclamation, a recrudescence of malaria took place on a scale unparalled in pre-reclamation annals; also, the scheme of improved reclamation of the hydraulic type of the district of Adria, where the unforeseen increase in malaria for four years in succession created considerable stir; and he mentions the fact that in spite of similar reclamation schemes malaria is still severe at the splendid Ricasoli farms near Grosseto and on the Rizzolo property within the limits of the municipality of Francofonte. The question of the density of the population and the economic condition of the people in the areas affected by these reclamation schemes is a matter of great importance. *A priori*, it would appear that, in the case of schemes financed by companies or private owners for sake of profit, the smallest possible number of employees will be engaged. As is well-known also, the economic condition of the agricultural population in certain parts of Italy, where reclamations have been made, is deplorable. Celli frequently inveighs against the agrarian feudalism existing in many parts of Italy under which the land still remains in the hands of the few. Referring specially to the Campagna, he remarks—"Unfortunately such a state of feudalism could not be changed here, as it was in northern and central Italy at the time of the communes and afterwards during the French Revolution. The Italian revolution has certainly made it worse, secularising the ecclesiastical properties, and substituting for religious communities capitalists or speculators who acquired the lands at a low price and make use of them for their own profit . . . . The law on agrarian sanitation of the Agro-Romano has not had the courage to break up the small but omnipotent band of proprietors, privileged more than they deserve, nor to improve the agrarian contracts, nor to prevent the organized spoliation of the tillers of the soil."

"In olden times", he says, "it was the custom in order to afford opportunities for improvements, for the rents to be paid at long intervals and for the workers to contract directly with the agent or the proprietor of the land, while to-day all contracts with few exceptions are made through

the *caporale* whose power is as absolute as it is unjust. He puts whole families in his absolute power by advancing small sums of money to them . . . . It is grievous to see how, for their convenience, to save themselves the trouble of dealing directly, as all the employers of every civilized country do, with the workers, our rich leaseholders and landlords permit such a condition of things to continue, which besides being contrary to all the usages of the most rudimentary civilization, strongly predisposes to the spread of malaria"

236. The following passage taken from an article on Italy in the latest edition of the British Encyclopædia throws further light on Celli's views and helps to explain the failure to mitigate malaria reported of a number of the more recent schemes of bonificazione :—

"In Liguria, on account of the comparative rarity of large estates agricultural labourers are in a better condition. Men earn between 1*s*. 3*d*. and 2*s*. 1*d*. (annas 15 and Re. 1-9) a day, women from 5d. to 8d. In Emilia, the day labourers, known as *disobligati* earn, on the contrary, low wages, out of which they have to provide for shelter and to lay by something against unemployment. Their condition is miserable. In Tuscany, however, the prevalence of Mezzadria, properly so called, has raised the labourer's position Yet in some Tuscan provinces, as for instance that of Grosseto, where malaria rages, labourers are organized in gangs under "corporals", who undertake harvest work. They are poverty stricken and easily fall victims to fever."

### 129—Summary and Recapitulation.

237. The results of the above discussion may be briefly summarized in tabular form :—

**The Influence of the various Factors concerned in the Amelioration of Malaria by Bonification.**

| FACTORS. | Effect on Anopheles. | Effect on number of population | Effect on Prosperity. |
|---|---|---|---|
| A.—Regulation of surface waters. | May cause a great reduction of anopheles. | May cause an increase if agriculture is improved and land tenure system allows. | May cause a great increase of prosperity if agriculture is improved and the land tenure system allows. |
| B.—Improvement of soil fertility— (a) Irrigation | May reduce anopheles if the basin or flood system is used, especially, for wet crops. The perennial system may lead to an increase of anopheles if village channels exist which can hold rain water in the monsoon. | Improves yields of crops very greatly and may cause increase of the local agricultural population, if composed of small landholders or tenant cultivators, provided the land tenure system is favourable. | Results in greatly improved prosperity both under *Raiyatwari* Settlement and where the land tenure system encourages small-land holders. |
| (b) Silt deposit | Silt bearing water is inimical to anopheles larvæ and also destroys aquatic vegetation. Hence it may greatly reduce anopheles. | Same effect as irrigation, in similar circumstances as regards land system | May increase prosperity of population. |

| Factors. | Effect on Anopheles. | Effect on number of population. | Effect on Prosperity. |
|---|---|---|---|
| (c) Sub-soil drainage. | May cause drying up of small surface pools and so reduce number of anopheles. | Brings water-logged soil into cultivation. Improved yield of crops by soil aeration, stimulating cultivation and leading to an increase of population if land system allows. | May increase prosperity of population greatly if land system allows. |
| (d) Manures ... | No effect on anopheles ... | May increase harvests and thus lead to an increase of population if land system allows. | May increase prosperity of population. |
| (e) Improved methods of tillage. | May reduce anopheles especially in case of wet cultivation. | May lead to an increase of population. | May lead to greatly increased prosperity. |
| C.—The choice of most suitable crops for local conditions. | May serve to reduce anopheles in certain circumstances, *e.g.*, rice cultivation, etc. | May lead to a great increase of population if land system allows, *e.g.*, rice will support a denser population than any known crop. Valuable crops, such as jute, sugar cane, cotton, may also stimulate increase of population. | May lead to greatly increased prosperity if land system allows. |
| D.— | | | |
| (a Increase of population | Probably has no effect on anopheles. | Leads to further increase of population if conditions favourable. | Increase of population does not necessarily increase prosperity but is an index of prosperity. |
| (b) Increase of prosperity. | May result in reduction of anopheles by improved sanitation | May lead to rapid expansion of population. | Increase of prosperity stimulates development and thus may lead to further prosperity. |

238. The facts that have been recorded regarding conditions in Italy serve to emphasize the tremendous importance of the human factors that have been discussed in relation to the epidemiology of malaria. In Italy the earlier projects of "bonificazione" which have proved so successful in ameliorating malaria have been carried out in areas such as the Val-di-Chiana, where the land system encouraged the multiplication of a class of small cultivators, who possess certain definite rights in the soil they tilled. Many of the later schemes, on the contrary, have been designed at the instance of non-resident capitalists, in areas possessed of a totally different system of land tenure. In these circumstances, fine engineering projects aided by scientific methods of agriculture, while proving highly remunerative to their owners, appear to have failed in a most signal manner to bring about the amelioration of malaria. The lesson to be drawn from this fact is that, while thinking of the water that requires regulation, we must not forget the needs of the soil, the crops or the people. It is the people especially whose social and economic condition requires to be improved. And in Bengal, where most of the land is in the hands of small cultivators, this can be accomplished by increasing the productiveness of the soil by irrigation and the regulation of the surface and sub-soil water generally. Increasing both the supply

and regulating the distribution of water by irrigation projects, and fertilizing the soil by means of silt deposits will improve the crops and increase the food supply of the country, while at the same time it will diminish the number of anopheles mosquitoes and lessen malaria very greatly. The resulting increase of population and prosperity will also conduce to the same great end.

### 130—Conclusions.

239. The facts that have been discussed in this chapter support the following conclusions :—

I. Bonification includes measures for the regulation of all of the following :—

(*a*) Water-supply.
(*b*) Soil-fertility.
(*c*) Food supply.
(*d*) Population.
(*e*) Agricultural prosperity.
(*f*) Anopheles mosquitoes.

Bonification influences favourably the relations of these various factors one to the other.

II. Measures of bonification can be applied in Bengal so as to reduce malaria very greatly.

III. Irrigation is the method of bonification particularly applicable to the decadent deltaic tracts of Bengal.

IV. Irrigation will increase soil fertility by silt deposit and improved drainage, thus encouraging cultivation of the land, increasing the food supply of the people, and promoting the prosperity of the country as a whole.

V. Under the system of land tenure common to the greater portion of Bengal, whereby most of the land is held by small tenant cultivators, irrigation will tend to check decline of population and will increase especially the prosperity of the agricultural classes, who form the bulk of the rural population.

VI. In the conditions peculiar to deltaic areas and which exist in the greater part of Bengal, irrigation and the improvement of wet cultivation, including the cultivation of rice, promises to reduce the number of anopheles mosquitoes and thus lessen the prevalence of malaria.

VII. That in the circumstances stated a great amelioration of malaria may be expected to result from measures of bonification applied in the form of suitable irrigation projects.

## CHAPTER IX.

### Conclusion.

240. The first main conlusion at which we have arrived as a result of the study of malaria in relation to agriculture in Bengal is that apart from the application of specific measures directed either against the malaria parasite or the anophelene carrier there is an immense field for the carrying out of anti-malarial projects based upon the principles underlying Italian "Bonificazione." As we have seen "Bonificazine" embodies measures designed for a double purpose, viz., to improve agriculture and improve health simultaneously. The second main conclusion to which we have come also relates to "Bonificazione." But in this case it is in respect to the particular type of bonification that is required. As we have already seen, *in Bengal this happens to be irrigation.* This is something new. At one time everybody thought that drainage was what was needed. But experience has shown that agricultural drainage schemes may be very dangerous expedients in Bengal, sometimes doing harm rather than good. All the recent evidence goes to show that what is most needed in Bengal is a large increase in the available supply of moisture. In other words "*Irrigation must be the watchword of Bengal rather than Drainage.*" The drying up of the country has already done immense harm. What is needed is the restoration of a healthly flow of water. This cannot be accomplished by the removal or reduction of the water but only by increasing the water-supply as much as possible, aiding its distribution and encouraging its flow. In other words. by irrigation.

241. *Necessary conditions for irrigation.*—It is all very well to talk of irrigation the engineers will say, but before you can have irrigation three conditions at least must be fulfilled: (1) there must be a sufficient supply of water available; (2) the water must either be available at such a level that will enable it to be passed to the places that require it by gravity, or it must be raised to such a height artificially; and (3) the supply must be available at the season of the year when it is actually needed. The suggestion that Bengal is badly in need of an irrigation policy is certain to be criticised. It will be said, for example, that the two existing irrigation systems in Bengal, viz., the Eden Canal project and the Midnapore project, are so little

appreciated that they do not pay their way; and it will be urged that neither of these projects have caused an amelioration of malaria, but on the contrary that they have brought about an increase of disease. It is generally said that the month of October and the dry weather is the period when irrigation is most needed, and it is certain to be pointed out that the available supply of water is usually very scanty at this time of the year. a fact that precludes any very large irrigation project. But if we get down to basic principles, and consider *firstly* what is the supply of water that can be made available for irrigation purposes; and *secondly*, how we propose to use this water for the double purpose of benefitting agriculture and diminishing malaria, much useless discussion will be prevented.

242. *The sources of water-supply in Bengal.*—Bengal is the best watered province of India. The rainfall is heavy, varying from a minimum of 50 inches in the west to a maximum of 150 to 200 inches in the north and the south-east of the province. But the rain that actually falls on the surface of the country is only a very small part of the available supply of water. Bengal derives an immense amount of overflow water from contiguous and even distant provinces. The catchment areas of the Ganges and Brahmaputra together extend over a million square miles which gives some idea of the extent to which Bengal is indebted to other provinces for her available water-supply. But the visible water-supply which includes both the rain and the water in pools and lakes and river channels is not the only available supply. For there is in addition an enormous invisible supply of water held up in the interstices of the soil. A foot of sand will hold six inches of water, a foot of loam four inches, and even clay will take up a considerable amount of moisture. Hence the soil acts as an enormous reservoir fed by the rain, and the overflow and percolation from rivers and water-course. Like the water on the land surface, moreover, which always flows from higher to lower levels on its way to the sea, the underground water is also in a state of flow below the surface of the ground slowly passing to the sea.

243. *Special importance of the ground water.*—Underground water can always be found by digging a hole deep enough in the earth. As we pass downwards the soil becomes more and more moist until eventually we reach a zone that exudes water, so that a small pool forms at the bottom of excavation. This free water is the subsoil water, and we have reached the "spring level" or the

"water table" as it is sometimes called. In some countries we may have to dig down many feet before we reach the subsoil water. But in deltas like Bengal the water table is very near the surface. The ground water has a most important bearing on plant life in general and on agriculture in particular; hence it is of immense importance also to irrigation. The majority of plants depend more upon ground moisture than upon either rain or surface water. In fact, both rain and surface water are chiefly of service to plants because they keep up the supply of ground moisture Plants vary in their requirements in respect to moisture. Some need a lot of water, others only a moderate amount and some can exsit on very little. Crops are roughly classified as "dry crops" and "wet crops" respectively. But these terms hardly express the great difference between them. Wet crops, for example, not only need much more water than dry ones. they also require to be grown much nearer the water table than dry ones do, because they are shallow rooted. Wheat and cotton are both dry crops, and wheat and cotton plants possess long tap roots which can penetrate deeply into the soil in search of moisture. Hence wheat and cotton are found growing in relatively dry areas, where the subsoil water is often many feet below the surface. Rice and jute, on the other hand, are wet crops with relatively shallow roots. Thus rice and jute grow luxuriantly in delta areas where the supply of water is abundant and the subsoil water is very near the surface. As 75 per cent. of the total crops grown in Bengal are "*wet crops*" it is obvious that both the supply of water and the relative height of the subsoil water are of immense importance to agriculture. We are now in a position to begin to understand the requirements of Bengal in respect to irrigation. As we have seen 75 *per cent.* of all the crops grown in Bengal are wet crops, including rice, jute and sugar cane. But these three sorts of wet crops actually occupy nearly 95 per cent. of the net cropped area and with the exception of a small area under summer rice, they occupy the land during the height of the wet season, when the supply of water is relatively abundant and the subsoil water is very near the surface. Bengal requires, in fact, flush, flood or inundation irrigation during the *kharif* season. In this respect Bengal is very different to drier and more elevated areas, where the main harvest is composed of dry crops, that mostly occupy the land during the dry season, when the supply of surface water is relatively scanty and when the subsoil water is

often many feet below the surface. For in these latter areas it is *rabi* irrigation that is mostly required in the dry season of the year.

244. *Types of irrigation.*—We have now gained a very general idea of the water-supply that is available in Bengal, and also learnt when most water is needed for agricultural purposes, and where in the soil it needs to be supplied to meet the requirements of the principal crops. We can now take a brief glance at the various types of artificial irrigation that are in common use in countries where such irrigation is practised in order to arrive at some conclusions regarding the particular method or methods of irrigation that are likely to be of most service in Bengal. The simplest type of irrigation is inundation irrigation. This is in use in almost all hot countries in which the rivers rise in flood during a certain season of the year. This sort of irrigation has been practised in Egypt for 7,000 years. and is largely adopted in some parts of the Punjab, where inundation canals are in use, and also in Sind. Inundation irrigation is also practised in Siam, Cochin China and China proper. In many parts of Eastern Bengal, natural inundation irrigation is largely employed. All that is required for this sort of irrigation is a system of branch channels taking off from the main rivers and so arranged that when the water in these rivers rises above a certain height water can flow through the branch channels into the fields. In the course of thousands of years inundation irrigation was carried to a high pitch of perfection in Eyypt by the construction of huge basins adjacent to the Nile that could be filled to a given depth with water, when the Nile rose in flood, by means of inundation canals ; and that could be emptied again into the Nile, when the river fell, through drainage or escape channels constructed for the purpose. The inundation canal systems of the Punjab and in Sind appear to be of a more primitive type than those of Egypt. But they are based on very similar principles, being designed to take off water from the rivers when the water rises to a certain height in the flood season, and to lead that water to the fields on which the crops are to be grown. As we have already seen in a previous chapter, the irrigation systems of China, Siam and Cochin China are worked on very similar principles. Inundation systems of irrigation are mostly used to assist in the cultivation of rice and similar wet crops.

245. *Flood or flush irrigation.*—A further development of inundation irrigation from rivers is to be seen in the

artificial arrangements adopted in the deltas of the Cauvery, the Krishna and the Godavery in Madras and the Mahanadi in Orissa, and in certain other countries. In these places it has been found possible to extend very greatly the area of cultivated land under command from the river by raising the level of the flood artificially. Weirs or anicuts or barrages are employed for this purpose. The effect of these contrivances is to impound the water in the river channel so that it is compelled to rise to a certain height before it can escape over the weir or anicut or pass through the openings in the barrages. In this way, a certain "head" is obtained above the weir, which enables a larger supply of water at a high level to be drawn into the canals that take off above the weir. anicut or barrage. This arrangement possesses great advantages over the simplest form of inundation irrigation, because whether the flood in the river is a high or a low one it is always possible to secure a supply to fill the canals, and thus irrigation is more constant and the crops are consequently more secure.

246. *Tank and bund irrigation.*—Flush irrigation may also be practised from large tanks or "bunds" constructed either for the purpose of holding up rainfall or in order that they may be filled from rivers or streams by means of small canals designed for this purpose. Tank irrigation for rice cultivation is very common in Madras and "bund" irrigation systems are used in Chota Nagpur and parts of Bihar and the Central Provinces. A similar system of irrigation used to be common in Bankura, Burdwan and Birbhum. Burdwan, for example, is supposed at one time to have possessed nearly 50,000 irrigation tanks. Even now it is reported that over 400.000 acres in Burdwan and 200,000 acres in Birbhum are irrigated from tanks. Tank irrigation is useful in several ways. When the tanks are at a sufficiently high level water can be passed on to the surface of the land by gravity. If the water level falls, the water can be raised artificially and passed on to the fields. Besides this tanks serve the purpose of assisting by percolation to keep the level of the subsoil water fairly high.

247. *Perennial irrigation.*—Perennial irrigation is the term applied to systems of irrigation designed to supply water throughout the year but chiefly for use in the dry season. Systems of this sort usually depend for their supply upon rivers in which the water can be impounded and raised to a given height by means of weirs or dams, so that it can be fed to the fields through a system of high

level canals. Now-a-days it is customary, wherever possible to construct huge reservoirs or artificial lakes somewhere on the course of a river by building immense dams across a narrow part of the river valley. The water so impounded is afterwards passed to the fields as required through a system of distributory channels. Perennial irrigation is specially valuable for assisting the growth of dry crops. Nearly all the modern canal systems in the Punjab and United Provinces are arranged for perennial irrigation, and the water is used for wheat and other dry crops. Perennial irrigation has many advantages and some disadvantages. It is a great advantage, for example, to have an abundant supply of water during the dry season when many valuable money-making crops can be grown, which otherwise could not be cultivated. On the other hand, perennial irrigation may lead to the rise of the subsoil water level to an inconvenient height, with bad results in the shape of water-logging of the soil, and the production of saline efflorescence or "reh" as it is called. "Reh" is due to the evaporation of moisture during the dry season from the surface of water-logged or semi water-logged soils. This evaporation leads to a concentration of salts near the surface. It frequently occurs in the Punjab and United Provinces along the course of badly aligned canals constructed at too low a level. Adequate subsoil drainage is the only remedy for this sort of thing. "Reh" is practically unknown in areas where flood or flush irrigation is practised for the growth of wet crops.

248. *Lift irrigation.*—Lift irrigation depends upon the use of water from rivers or tanks or wells, raised by artificial means. All sorts of contrivances are used for raising water, but pumps are now usually employed where relatively large areas are to be irrigated by lift. Owing to the great expense of pumping or otherwise raising water artificially, this sort of irrigation is usually adopted for dry crops and is rarely employed for wet crops other than sugar-cane which brings in a heavy gross return. Lift irrigation has been employed in Carolina for irrigating rice fields, however. Lift irrigation has one great advantage: because of the expense of raising the water there is little temptation to overwater the land so as to produce water-logging; moreover, the very raising of the water diminishes the risk of water-logging very greatly.

249. *Tidal irrigation.*—It is sometimes possible to make use of the tides, which back up the fresh water in a tidal river, to obtain a supply of sweet water for irrigation

purposes. The water is passed at high tide through tidal sluices into low-lying rice fields protected from inundation by means of embankments. The excess can be removed by opening the sluices at low tide. Irrigation of this sort is practised in Carolina and in other countries, in areas situated near the mouths of tidal rivers.

250. *Irrigation systems in Bengal.*—Reference has been made to the Eden Canal and the Midnapur Canal projects in Bengal. These irrigation systems differ in detail but not in principle. The Midnapur system is fed by means of canals taking off above weirs or anicuts constructed across the Kosai river; the Eden Canal System, on the other hand, is fed from the Damudar by means of sluices. There is no permanent weir across the Damudar but a temporary bund of sand is usually built across the river after the flood season with a view of raising the level of the water so that a larger amount can be fed into the canal. Both the Eden Canal and the Midnapur project are used almost entirely for the growth of wet crops and chiefly for rice cultivation. But they do not appear to be worked on the plan adopted in the Madras deltas, which allows of a very large supply of water for flushing the fields during the flood season. On the contrary, irrigation from both the Eden and Midnapur systems is restricted as far as possible to the early and late parts of the season. Water is supplied only to those who have taken water leases, and leases are issued on the basis of the average available October supply. It is considered that from the point of view of the rice crop October irrigation is of most value, because it gives most security. In practice, irrigation from these two systems means *October irrigation*. This fact is mentioned because it is of immense importance from the point of view of malaria; and it explains why neither the Midnapur nor the Eden Canal systems have been effective in reducing malaria. By the time October has been reached, the majority of the anopheles mosquitoes that are likely to spread malaria in the locality have already been produced, under conditions which permit them to develope to the best advantage, *i.e.*, in areas well provided with breeding places, not too abundantly supplied with water so as to be flushed effectively and thus rendered innocuous by a large excess of water. The lands commanded by both the Midnapur and the Eden Canals would probably be greatly benefited if the canals were allowed to run to their fullest extent during the flood season, for the purpose of flushing the largest possible area with silt laden

river water. But this procedure is rendered difficult owing to two facts : (1) the possibility of causing damage to certain portions of the area by the excessive flooding of the land which might occur in the absence of efficient drainage channels for removing the excess of irrigation water ; (2) the water-lease system, which being based almost wholly on the available October supply, gives an impression that people only contract for October water and have no claim to a supply at other times. It is felt also that by feeding the distributories during the flood season, others than those paying leases would benefit. When these facts are borne in mind it is not difficult to understand why the Midnapur and Eden Canal systems cannot possibly effect a reduction of malaria. It is *because of the manner in which they are worked.* At this point, it is convenient to digress for a moment and explain the relation of *perennial irrigation* to malaria. *Perennial irrigation*, as we have seen, is usually employed for wheat, cotton and other dry crops that require water in the dry season. These long-rooted dry crops do not flourish if the subsoil water level is too high. But there is a danger that if the land is too heavily watered, the subsoil water level may be raised too high and the crops suffer from water-logging. In these areas, therefore, the canals and village distributory channels of the irrigation system are as far as possible kept empty of canal water during the wet season when irrigation is not required. But during the rains it is quite impossible to keep the channels free of small pools of rain water. As a result, anopheles mosquitoes breed in large numbers in the partially empty channels and malaria becomes rife among the population living near at hand. This appears to be the explanation of the increase of malaria that has taken place in the Punjab and elsewhere in association with the introduction of *perrennial irrigation* for dry crops. Flush irrigation, as practised in the Madras deltas, does not cause an increase of malaria. On the contrary it makes the areas using it less liable to the disease

251. *The sort of irrigation required in Bengal.*—We have seen that nearly 95 *per cent* of the net-cropped area in Bengal is occupied by wet crops consisting mainly of rice, with a smaller proportion of jute or sugarcane in certain areas. We have seen also that the bulk of these crops occupy the land during the wet season when the rainfall is heavy, the rivers are in flood, and the subsoil water level is nearest the surface. Moreover, we have

learnt that at this period (which may be roughly stated as including the months June to October) malarial infection ordinarily tends to spread; but that in the parts of Bengal that are most amply supplied with water at this season of the year, enjoying a sort of natural flood or flush irrigation, malaria is reduced to a minimum by the abundance of water, while at the same time the wet crops are greatly benefited by the same ample water supply. We have learnt also that in the Madras deltas and elsewhere, where wet crops are grown with the assistance of abundant flush irrigation in the wet season from the rivers that are always in flood at that period, malaria is reduced to a minimum and on the other hand the harvests are greatly benefited. When these facts have been clearly grasped, it will be apparent (1) that the sort of irrigation required in Bengal for the joint purposes of improving agriculture and reducing malaria, must be of a very similar kind to that of Madras, or Sind, or the Punjab inundation canals, viz., flush, or flood or inundation irrigation; (2) that it must aim at the utilization of the largest possible amounts of water than can be drawn off with safety from rivers *during* and not *after* the flood season; and (3) that in these circumstances there is no need to worry about the subsoil water level being raised too high; on the contrary, the aim must be to raise it and keep it as high as possible during the wet season so as to benefit crops and reduce malaria. "How," it may be asked, "can these conditions be fulfilled and flush irrigation of this sort be extended where it is most needed, both for purposes of agriculture and for health?" The answer is clear. In many parts of Bengal, especially in the Burdwan and the Presidency divisions, the rivers rise in flood above the level of the land during the wet season, and are only prevented from overflowing the country by means of embankments. These embankments are in many cases already pierced with sluices for the passage of water. But with few exceptions these are rarely opened at present. There is no question whatever that in the areas mentioned it would be possible to design and carry out inundation irrigation projects that would be of immense benefit to the country. Burdwan and Murshidabad districts may be specially mentioned as areas in which inundation irrigation is easily possible as far as the supply of water is concerned owing to the fact that river water is at present excluded from the country at the very time it is most wanted; by means of high embankments.

Recently a scheme was drawn up for irrigation in the Burdwan district, where irrigation is a most imperative necessity, due to the fact that the country is being gradually dried up, the subsoil water-level falling in the dry weather to a great depth below the surface, and the net-cropped area having been reduced, owing to lack of water, by nearly 50 *per cent.* in thirty years. But this scheme was based on wrong principles and a complete misunderstanding of the real needs of the country. Consequently, although it would have been much better than nothing at all, it would not have been so useful as it might easily be made. In the first place, it was designed chiefly to make use of the available October supply of water. It was neither the flush irrigation of the Madras deltas, nor the inundation irrigation of Sind nor the perennial irrigation of the Punjab, but merely the repetition on a large scale of the sort of irrigation that is already carried out by the Eden Canal and Midnapur Canal projects. This sort of irrigation is not specially effective from the point of view of agriculture, neither is it of any use for the reduction of malaria. It is a sort of compromise. Those responsible for designing the Burdwan scheme would no doubt say that what they aimed at was to ensure a supply of water in October, a very critical period for the rice crop; and that owing to heavy rainfall water is not really needed earlier than this, except sometimes to assist the planting of rice early in the season. But this point of view ignores the fact, pointed out in an earlier paragraph, that the height of the water is all important, to wet crops especially, and that the filling up of the vast subsoil reservoir is one of the most important functions of an irrigation system working under conditions extsting in Bengal. On the average, the dry weather level of the subsoil water in the Burdwan district is about 25 feet from the surface. The soil is chiefly loam, which we have seen requires about four inches of water to the foot to saturate it. Therefore, on the average, Burdwan district requires 100 inches of water to raise the subsoil water to such a level that wet crops like rice can be cultivated. But the rainfall is only about 50 inches, and flood water from the rivers is excluded from the country by means of embankments. In these circumstances, it should be obvious that wet cultivation must necessarily be limited to those localities, which can obtain a large supply of the moisture they require, either by percolation or by overflow from adjacent areas. In any case, much less than 50 per cent. of the total area of the

Burdwan district can be cultivated with wet crops because the whole available rainfall would only just permit of the subsoil water level being raised to the surface of that proportion of the total area, and would allow of no further supply for irrigation. Formerly, it may be remembered, 75 per cent. of the whole Burdwan district was under cultivation, and it was the wealthiest district of Bengal. At that time 50,000 irrigation tanks were in operation, and besides this the Damudar river used to flood many parts of the country every year through breaches in the embankments. The subsoil water in these circumstances must have been at a very high level, with the result that every drop of October rainfall could be fully utilized for the growing crops. Circumstances are very different at present. For, after the rains cease the subsoil water level falls very rapidly, and if the August and September rains have been scanty the small rainfall ordinarily received in October may be quite insufficient for maturing the crops, because the subsoil water is then too low to enable it to be fully utilized for the purpose. Flood or flush irrigation during the wet season is needed in Burdwan (and in other areas also) so that October rainfall or October irrigation can be made effective, by reason of the subsoil water level having been kept up at a sufficiently high level.

252. *Irrigation for restoring flow in the rivers*—Flood or flush irrigation from the rivers during the flood season is needed for another purpose,—filling up with water the vast underground reservoir of the soil and so providing a supply of water to feed the rivers by percolation during the dry weather months. This is an aspect of irrigation which has been altogether ignored in Bengal. But it has received a considerable amount of attention in other provinces. Recently, Mr. F. W. Woods. late Chief Engineer, Irrigation Works, Punjab, has pointed out, as the result of a careful study of past records relating to the Indus, that the dry weather flow of that river has increased enormously since 1854, when there were no winter canals whatsoever in the Punjab. He estimates the absolute increased dry weather flow in 1908, 1909 and 1910 at 15,000 cusecs; notwithstanding the fact that the Punjab canals were withdrawing an additional 18.000 cusecs at the same time. Figures for 1916-17 supported the same contention, that the dry weather flow of the Indus has been actually increased rather than diminished since irrigation works have been extended.

Mr. Wood's explanation of this apparent anomaly is as follows :—

*Alluvial storage.*—The explanation of these apparently paradoxical phenomena appears to be that the alluvial soil of the Punjab plain acts as a storage reservoir, regulating by absorption and subsequent exudation from season to season a considerable portion of the water of the rivers and canals that pass over it. The mean elevation of the Punjab plains, at a distance of about 360 miles upstream of Sukkur, is about 450 ft. higher than the low-water level of the *Indus at Sukkur*. About 60 per cent. of the water withdrawn from the rivers by the canals percolates from the canals and irrigated fields into the subsoil, thereby raising the level of the subsoil water-table locally ; and when the subsoil water has thus risen above the low-water levels of the rivers adjacent, it percolates back gradually into the river-channels, and incidentally prevents the rivers from losing by percolation outwards the 40 per cent. of their flow, which they were losing in Cunningham's days. There is, in fact, good ground for the belief that the Punjab canals and sub-soil have been as beneficial in the storage and regeneration of water-supply for the Indus as ever was the Biblical widow's cruse in the matter of oil. Nevertheless, since the summer flow of the Indus is more than five times greater than its winter flow, it would appear to be advisable to aim at utilising as little as possible of the relatively clear and scanty water-supply of the winter and as much as possible of the far more abundant summer flow of the rivers, which is also far more richly charged with fertilising silt.

253. *Alluvial storage for Bengal.*—Alluvial storage is of immense importance to Bengal for the maintenance of the rivers that are in good order ; for restoring the dry weather flow in water-courses that have already undergone a certain amount of decay ; and for providing areas at present subject to distress from lack of water in the dry weather with that relief they most require. The method indicated by Mr. Woods, viz., the utilization of river water in the flood season to the fullest extent possible, is the very method of irrigation that is required for reducing malaria and at the same time increasing both the area under cultivation and the yield of the wet crops that are the main-stay of Bengal. Experience shows that in Bengal there is no danger in filling up the alluvial storage reservoir to its utmost possible capacity, for, contrary to what happens in more elevated and drier areas, localities in Bengal possessed of

the highest subsoil water level are as a rule the healthiest. It is not a difficult matter also to fill up the alluvial reservoir if we remember that water tends to percolate very rapidly downwards owing to the force of gravitation, whereas it percolates very slowly in a lateral direction. Bearing this in mind, the principles to be followed should be (1) to prevent the rapid escape of surface water into rivers and water-courses, (2) to aim as far as possible at storing up surface water in tanks that may be used for irrigation and potable purposes, and (3) to aim at bringing as much water as possible from the rivers and water-courses during the flood season and passing it on to the surface of the country with a view to filling up the alluvial reservoir to its fullest possible capacity and keeping it filled as long as possible into the dry season, consistent with agricultural needs. If these principles are followed, the dry weather subsoil water level of the Burdwan and Presidency divisions, for example, will be gradually restored to its former level, and may even be made to approximate to that of Eastern Bengal districts where even at the lowest it is rarely more than 9 or 10 feet from the surface. If this can be done, an amount of water, equal at least to one-year's total rainfall, can be kept stored up in the soil reaching to a height of from 10 to 15 feet above the present dry weather subsoil water level of many areas. This will have very far reaching consequences. For, not only will it gradually restore the dry weather flow in the rivers, but it will also tend to raise the high flood level of many of the channels, especially during the early and later portions of the flood season. This is very important, because it will eventually enable flush irrigation to be extended to areas to which existing river levels do not at present allow.

254. *Recommendations.*—Two recommendations only need to be made in respect to the principles of "*bonification by irrigation*", which I have attempted to outline and explain in this report. The first relates to the immediate application of these principles and the second to future action. As regards immediate action, the general lines to be followed have been indicated in the course of the report, and all that need now be said in further explanation is this: Every possible encouragement should be given to private persons, public bodies and voluntary institutions to push forward irrigation projects of every possible kind, including the construction and restoration of irrigation tanks, the excavation and re-excavation of khals and water-courses of all kinds, and the care and conservancy of river

channels generally; the aim being to conserve and store up water on the one hand and to promote the healthy flow of water on the other; always remembering that the too *rapid and too complete removal of water either from the surface of the country or the subsoil is fraught with a considerable amount of danger to health, to agriculture,* and to the regimen of the rivers themselves. As regards the future action that should be taken, what I would urge, with the strongest possible emphasis at my command, is the need for the appointment of an Irrigation Commission for Bengal, capable of investigating the needs of the country in a statesmanlike and impartial spirit. Among others, such a Commission should be empowered to obtain the views of irrigation experts familiar with the various types of irrigation that have been briefly described in this chapter. This is all the more necessary because, I believe, Bengal does not possess at the present time a single officer who can claim practical acquaintance with the inundation irrigation systems of the Punjab and Sind, respectively; the flush irrigation systems of the Madras deltas; the basin irrigation of Egypt and the other forms of flood irrigation practised in Siam, Cochin China and elsewhere. In final conclusion, I would point out that, at the present moment, there is cultivable land in the Burdwan and Presidency divisions equal in area to the whole of the cultivation in Egypt but which is now lying waste or fallow for lack of the necessary irrigation water. At the same time, the very flood water needed so badly for the irrigation of the country is actually passing each year unused to the sea, being confined often by embankments to river channels like that of the Padma, the Ganges and the Damudar and many other smaller streams. *All that is wanted is the genius that can devise means for bringing the water that is at present being wasted to the land that is now lying waste.* The future of Bengal is bound up with the solving of this great problem. For the health of the people, the success of agriculture, the welfare of the whole community, the prosperity of the railways and the commercial supremacy of the city and port of Calcutta are all bound up with this great question, how best to bring back to the waste lands of the delta, the life-giving flood waters of the rivers, of which they have been so long deprived. The various appendices attached to this report give further information regarding the principles to be followed in the attempt to reduce the malaria of Bengal by the utilization

## APPENDIX I.

### Some Economic Aspects of Bengal Malaria.

1. One hundred and thirty years ago Malthus, an obscure country clergyman, stated in his now famous essay that "everything depends on the relative proportions between population and food." Fifty years later Darwin was led to apply this doctrine to the whole animal and vegetable world, and the results of his work, published long afterwards, laid the foundations of the modern science of biology and produced a revolution in every department of thought. The laws of population enunciated by Malthus and extended by Darwin have thus exerted a profound influence upon nearly every branch of knowledge; and their fundamental importance in connexion with the study of epidemiology and the problem of disease prevention is at last being recognized.

2. Every organic being naturally increases at so high a rate that, if not destroyed, the earth would soon be covered by the progeny of a single pair. There is no exception to the rule; even slow-breeding man has doubled in twenty-five years. But a continual doubling of his numbers every quarter of a century cannot take place. In any long settled country mankind cannot increase at anything like the maximum rate. The fundamental reason of this is to be found in the tendency to diminishing returns from the soil. On any given area that tendency shows itself for all agricultural produce. The tendency towards increase in population must then be counteracted; and it may be counteracted in two ways, to which Malthus gave the names 'positive' and 'preventive' checks. By positive checks he meant those which cut down numbers already brought into the world—starvation, disease, war, misery in all its forms. By preventive checks he meant those which prevent numbers from being brought into the world.

3. The present paper concerns disease, one of Malthus' positive checks, which operates through a high death-rate, or in other words through an excess of deaths.

4. Bengal is a huge swamp, peopled, as the *Raghubansa* puts it, with eaters of rice and fish and dwellers in boats. "A good rice swamp is a bog at all seasons, and at one season a bog covered with water," says Adam Smith; and he points out, it is "unfit either for corn or pasture and the lands fit for those purposes are not fit for rice." But it has one great advantage: "A rice field produces a much greater quantity of food than the most fertile corn field." Rice itself is an aquatic grass which cannot thrive without ample water and which suffers from deficiency far more than from excess. It can adapt itself to floods but it cannot stand drought. The long-stemmed varieties will grow 12 inches in 24 hours and withstand submerging for three days; and provided the crop is not drowned outright the greater the depth of water on the fields the better the yield of grain. Besides producing rice, swamps abound in fish, another valuable food of man. Hence rice-swamps supplied with sufficient water tend to become very densely populated. "The numbers of a population," says Darwin, "depend primarily on the

means of subsistence and this depends partly on the physical nature of the country, but in a much higher degree on the arts which are there practised."

5. Agriculture is the art most widely practised in Bengal; rice occupies 85 per cent. of the cultivable area, and jute, another swamp crop, a further 10 per cent., and as we shall see later, these facts have an important bearing on the density and growth of population which are by no means uniform throughout the country.

6. Bengal is divided by its main river systems into four natural divisions, viz., Western, Central, Northern and Eastern Bengal, respectively. Since the first Census of 1872, there have been remarkable variations in the rate of growth of the population in these four divisions as may be seen from the statements noted below:—

*Increase of population.*

| | Population in 1872. | Population in 1921. | 1872—1921. Increase per cent |
|---|---|---|---|
| Western Bengal ... | 7,604 661 | 8,039,704 | + 5·7 |
| Central ,, ... | 8,202,760 | 9,433,544 | + 27·1 |
| Northern ,, ... | 8,045,432 | 10,358,303 | + 28·8 |
| Eastern ,, ... | 10,980 504 | 18,650,139 | + 69·8 |

*Density of population.*

| | Density per square mile | | Increase |
|---|---|---|---|
| | 1872 | 1921 | |
| Western Bengal ... ... | 545 | 570 | + 25 |
| Central ,, ... ... | 424 | 539 | + 115 |
| Northern ,, ... ... | 418 | 538 | + 120 |
| Eastern ,, ... ... | 479 | 815 | + 336 |

7. The extraordinary development of the population in Eastern Bengal is due entirely to natural growth by excess of births over deaths; there are few towns and no important industries to attract immigrants; this natural division also, as a matter of fact, has lost rather than gained by migration. This area affords therefore an example of normal expansion occurring in an agricultural population living under relatively favourable conditions. Conditions are obviously very different in the other divisions, all of which possess important industries which attract immigrants in large numbers. Western Bengal, for example, possesses coal, iron and mills, etc., Central Bengal has a number of towns with many mills, and factories and Northern Bengal includes nearly 200,000 acres under tea. Estimates of the gain by migration from these and other causes are difficult, but the excess of immigrants over emigrants in 1901 and 1911, respectively, was found to be about 6·3 and 7·4 per cent. of the population in Northern Bengal and 5·8 and 8·8 per cent. in Central Bengal. Much of the expansion in this latter division is undoubtedly due to immigrants to its many towns. Western Bengal, on the other hand, lost nearly as much by emigration from certain of its rural areas as it gained by immigration into its towns and industrial tracts.

8. What would the present populations of Western, Central and Northern Bengal be, respectively, if they had expanded since 1872 by 69·8 per cent., the rate of growth which has actually occurred in Eastern Bengal? Western Bengal would have nearly five millions, Central Bengal nearly four millions and Northern Bengal over three millions more inhabitants; and the province as a whole would possess a population greater by more than twelve millions than it does at present; that is 58,605,420 against 46,481,690. Why is it that this expansion has not occurred? A partial explanation is to be sought in the fact that for a very long period the population of large areas in the several divisions has ceased to expand at a healthy rate; but a factor of even greater importance is the actual decline of population that has taken place in tracts covering many thousands of square miles. The statement below gives particulars of the area in each natural division in which population has shown a decline at each of the last five census enumerations.

*Area in square miles in which population has declined.*

| | 1872-81 | 1881-91 | 1891-01 | 1901-11 | 1911-21 |
|---|---|---|---|---|---|
| West Bengal ... | 7,149 | 5,027 | 1,428 | 5,339 | 11 515 |
| Central „ ... | 2,590 | 4,444 | 4,488 | 5,262 | 7 126 |
| North „ ... | 6,534 | 5,483 | 3,878 | 3,175 | 6,964 |
| Eastern „ ... | 6,476 | 1,109 | 2,180 | 1,388 | 465 |
| Total ... | 22 749 | 16.063 | 11,974 | 15,164 | 26,070 |

9. With the exception of the period 1872-81, the decline of population has affected a relatively small area in Eastern Bengal at each succeeding decade. The cause of the large area found decadent in 1881 was the storm wave of 1876, which affected much of Bakarganj and Chittagong and parts also of Noakhali and Tippera and resulted in an appalling loss of life. The figures for the last decade give the best idea of the relative conditions of the different parts of the province. They show that 83 per cent. of Western Bengal is decadent, 60 per cent. of the inhabited portion of Central Bengal is in a similar condition, and 36 per cent. of Northern Bengal is affected by decline of population, whereas in Eastern Bengal only 2 per cent. of the total area has shown a reduced number of inhabitants.

10. It may be that when population has ceased to expand rapidly it is merely because local circumstances, as for example the food supply, are not specially favourable to expansion. But an actual loss of population means very much more than a lessened rate of expansion. It points to some definite change in the climate or in other conditions vitally affecting the welfare of the population which has made a reduction of their numbers inevitable. The effect of such a change is likely to be very far-reaching, as Darwin has pointed out in his *Origin of Species*. "We shall best understand the probable course of natural selection," he says, "by taking the case of a country undergoing some physical change, for instance, of climate. The proportional numbers of its inhabitants would almost immediately

undergo a change, and some species might become extinct." "We may conclude," he adds "from what we have seen of the intimate and complex manner in which the inhabitants of each country are bound together, that any change in the numerical proportions of some of the inhabitants, independently of the change of climate itself, would seriously affect many of the others." What Darwin wishes to convey by this passage is that when a change occurs sufficient to affect the numbers or distribution of any living organism, animal or vegetable, the other organisms, living in the same area, are bound to be affected also. When, therefore, a change of climate or of local conditions has resulted in a decline of the human population living in an area, it is bound to be reflected in the flora and the fauna of the locality also. The history of Kassimbazar affords a striking example of this and incidentally serves as an illustration of the sort of change to which Darwin refers in the passage just quoted.

11. "The decay of Kassimbazar dates from the beginning of the nineteenth century," states the *Imperial Gazetteer*, "when its climate, which had previously been celebrated for its salubrity, underwent an unexplained change for the worse, so that the margin of cultivation receded and wild beasts increased." Here is an instance in which both the plant and animal life of the locality are noted as having been influenced as the result of a change which affected the human population. The receding cultivation and the increase of wild animals indicate a serious alteration of former conditions.

12. Knowing what we do of the causes of tropical disease, we can safely affirm also that a corresponding change took place in the number and distribution of such lower forms of life as anopheles mosquitoes and malarial parasites, and hence the "unexplained change for the worse" of the former salubrious climate. We shall have occasion to refer to the cause of the change of climate at Kassimbazar a little later. Meanwhile, we must return to the discussion of the larger question regarding the more recent serious depopulation of so many portions of Bengal.

13. Attention has already been called to the fact that a serious decline of population indicates that a definite change has come over the affected area; and as we have seen, the effects of such a change are not limited to man but are certain to exert a very marked influence also on both the flora and fauna of the locality, resulting in an increase of certain species and a decrease of others. This view is borne out by the evidence which shows that both the plant and animal life of the areas undergoing depopulation exhibit an increase in certain directions and a decrease in others, and many of these increases and decreases are of special importance to man from an economic standpoint, affecting as they do the question of available food supply very greatly.

14. The most prominent and best recognized change in relation to fauna is to be seen in the great increase of malaria. If we compare a map of the areas suffering from a decline of population with another showing the relative prevalence of malaria we shall see that there is a rough correspondence between them. Depopulation is, therefore, generally associated with intense malaria. Evidence points to the fact that in the areas in which the human population is declining, malaria has increased very greatly during the last sixty years.

*The relative prevalence of malaria.*

| | Fever indices. | | |
|---|---|---|---|
| | 1868 Per cent. | 1912 Per cent. | 1920 Per cent. |
| Western Bengal ... ... | 21·9 | 40·9 | 51·7 |
| Central „ ... ... | 17·3 | 32·3 | 44·9 |
| Northern „ ... ... | 22·3 | 23·7 | 33·5 |
| Eastern „ ... ... | 9·3 | 7·5 | 14·0 |

15. Burdwan, Birbhum, Bankura, Midnapur and Hooghly in Western Bengal were at one time relatively free of malaria and were regarded as sanitaria. Similarly Murshidabad and Nadia and a great portion of Jessore in Central Bengal were formerly healthy, and Pabna and Malda in North Bengal were also relatively salubrious. In Eastern Bengal, Tangail in Mymensingh, Manikganj in Dacca and the northern portions of the Faridpur district, which are now malarious, were formerly relatively free of the disease.

16. This admitted increase of malaria can only be explained on the assumption that there has been a corresponding increase in the number and distribution of anopheles mosquitoes and malaria parasites in the areas affected. Unfortunately, there are no actual observations on this point. But it must be remembered that the malarial parasite was only discovered in 1880, and the part played by anopheles mosquitoes in its transmission as late as 1898, long after this increase of malaria had taken place. Many healthy localities in which population is increasing usually show scanty signs of malaria. But anopheles mosquitoes of species capable of harbouring the malarial parasite are to be found everywhere and often occur in large numbers in these healthy areas. They do not, however appear to multiply greatly during the wet season as they do in the unhealthy areas, so that the period of their greatest prevalence does not correspond with that most suitable for the proliferation of malarial parasites. Meanwhile, it may be noted that there are grounds for believing that in the decadent areas anopheles mosquitoes are now far more prevalent during the period of July to October than they used to be, and that this change is associated with a greatly lessened supply of water.

17. Other important variations in the fauna of the areas undergoing depopulation are the notable decrease in fish of all kinds and the great increase in the prevalence of certain mammals, wild hog for example. The decrease of fish is generally recognised and has been reported on by Sir K. G. Gupta, I.C.S., and Mr. K. C. De, C.I.E., I.C.S. The increase of wild hog and other vermin is also generally admitted and is often ascribed to the increase of jungle. Both of these changes are important from an economic stand point; the reduction in fish, because it means a lessening of the food supply, and the increase of wild hog, etc, because it results in greater damage to crops. A further minor change in the fauna of certain of the areas now undergoing depopulation is the reduction in the number of silkworms produced. This is also a matter of economic importance to man.

18. We have now to consider certain changes that have taken place in the flora of the areas undergoing depopulation. As will be seen, many of these changes are of supreme importance to man from an economic standpoint.

19. The most noticeable change is the lapsing of cultivated or inhabited areas into jungle. This was previously noticed in the case of Kassimbazar, but it has become so apparent in later years as frequently to be accepted as a primary cause both of the general increase of malaria and of depopulation. Certain facts require to be noted about this increase of jungle. In the first place, it is confined almost entirely to the more elevated and drier localities, the high banks of the rivers and on village sites for instance, and it is especially noticeable in places where population has declined. In the second place, contrary to what is often stated, this growth of jungle, as the Nadia Fever Commission pointed out, "is of a kind that prefers a dry to a damp *habitat*." It is not swamp vegetation that increases, but trees and shrubs whose roots require a soil in which aeration occurs. This fact has a very important bearing upon the nature of the climatic change that has occurred in the areas undergoing depopulation.

20. Turning to the broad question of cultivated and waste land respectively, some idea of the relative distribution of the various classes of land may be got from the following tabular summary which gives the percentages for each natural division.

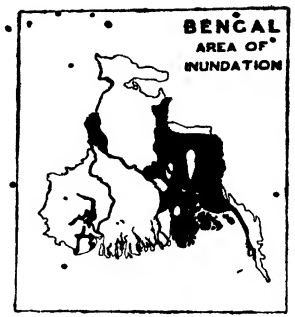
| | Percentage cultivable area cultivated | Percentage cultivable waste | Percentage current fallow |
|---|---|---|---|
| | Per cent | Per cent. | Per cent. |
| Western Bengal ... ... | 61 | 26 | 12 |
| Central „ ... ... | 58 | 18 | 24 |
| Northern „ ... ... | 71 | 14 | 15 |
| Eastern „ ... ... | 90 | 7 | 3 |

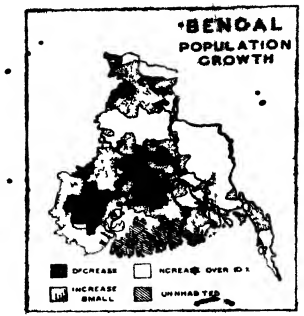
21. There is little statistical information regarding changes in the proportions of cultivated and uncultivated land respectively, but a few general statements are on record relating to particular areas. For example, it is reported that in Burdwan prior to the epidemic fever seven-eighths of the land was under cultivation, whereas the latest returns show only 47 per cent. of the cultivable area as being cropped. This latter figure compares very unfavourably with Dacca, where during the same season 92 per cent. of the cultivable area was cultivated. A progressive contraction of the cultivated area in Nadia has been reported by the successive Collectors. And a loss of fertility and consequent agricultural deterioration has been noted in many other districts of Central and Western Bengal and elsewhere. Take for example the following remark from page 50 of the Settlement Report of Faridpur: "It was impossible for landlords to enhance rent and to evict tenants *when the fertility of the soil was declining and land was gradually going out of cultivation.*"

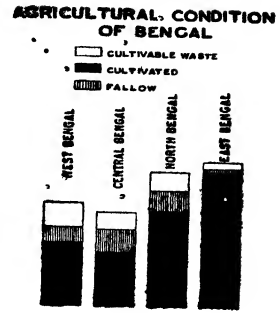
NOTE.—The italics are mine—C. A. B.

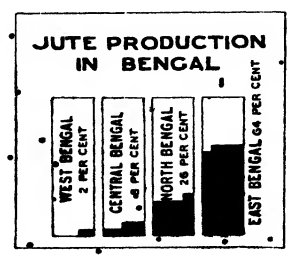
# SOME ECONOMIC ASPECTS OF BENGAL MALARIA.

By Dr. C. A. BENTLEY.



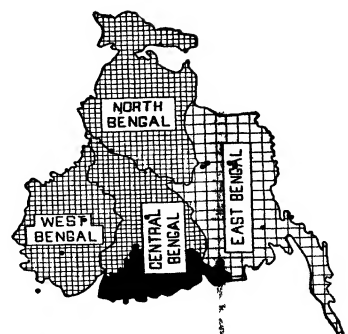
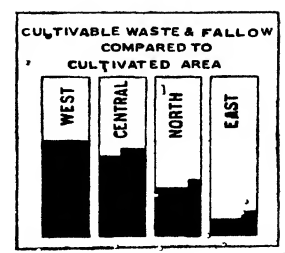




Diagram indicating proportion of roads and railways in each natural division.



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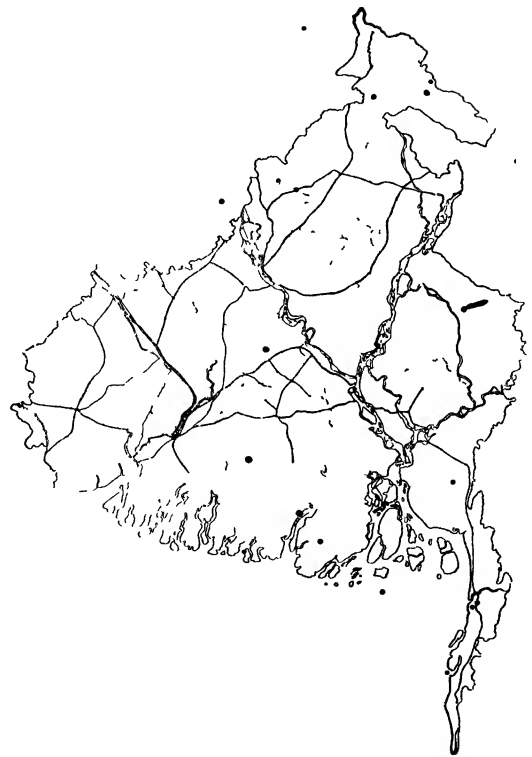
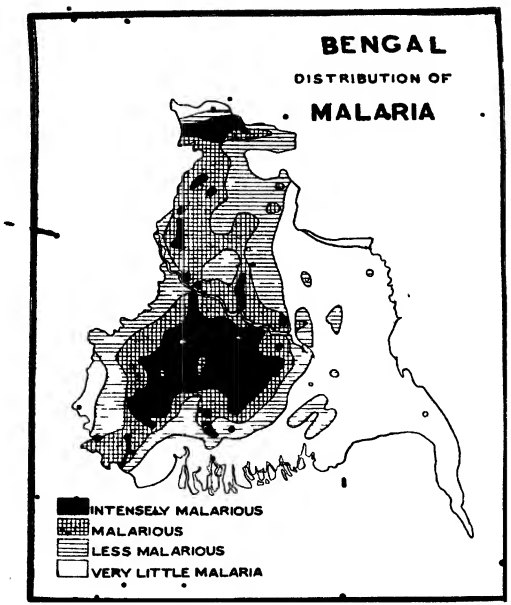


Roads and railways in Bengal in 1870.



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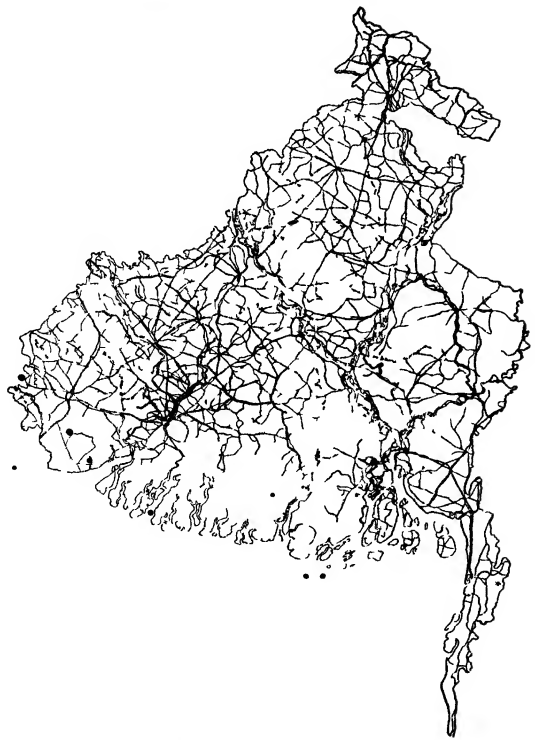
By Dr. C. A. BENTLEY.



Roads and railways in Bengal in 1920.

22. Taking into consideration the broad fact that only 58 and 60 per cent. of the cultivable area is under cultivation in Central and Western Bengal, respectively, compared with 90 per cent. in Eastern Bengal, it would appear, in view of the marked decay of population that has taken place in the former areas, that some climatic change has occurred which has affected the flora of these areas to such an extent as to diminish very seriously the food supply of the people.

23. When we come to examine in some detail the crops grown, certain very significant facts are brought to light. Take the character of the rice grown in different parts of the country. There are three main varieties of rice, *Aman* or Winter rice, *Aus* or Autumn rice and *Boro* or Summer rice. These different classes of rice flourish best in different situations and differ in the amount of water they require. *Aus* paddy grows on relatively high land and requires least water; *Aman* requires abundant water and *Boro* grows best along the edges of rivers or permanent swamps. The proportions of these three kinds of rice grown in different localities vary very greatly and depend primarily on the water supply. *Boro* paddy gives the most abundant yield, *Aman* paddy the finest grain and *Aus* paddy the smallest outturn and the coarsest rice. In spite of this fact *Aus* paddy is gradually replacing *Aman* in certain areas.

24. The *Gazetteer* of the Jessore district, for example, states that the area under *Aman* rice is contracting owing to deficient floods; and a comparison of the agricultural statistics of 1920-21 with those of 1906 shows that in Jessore the normal area under *Aus* has been increased by 10 per cent. and in Nadia by 50 per cent. Wherever the supply of water is scanty *Aus* paddy tends to replace *Aman*. The figures for individual *thanas* in the Faridpur district are very instructive in this respect, showing as they do that the extraordinary variation in the growth of *Aus* paddy in different parts of the district bears a relation to the water supply. "In the north of the district," says the Settlement Report, 'water for drinking and other purposes has become very scarce." The north of the district is malarious and in the malarious northern *thanas* of Pangsa, Bhushna Baliakandi, Goalundo and Faridpur the proportion of *Aus* paddy grown is from 34 to 46 per cent. of the total, whereas in the non-malarious more southern *thanas* it is very small, ranging from 6·3 per cent. in Kotwalpara to 7·5, and 7·9 and 9·6 per cent., respectively, in Madaripur, Gopalgapj and Muksudpur. The outturn of *Aman* rice varies greatly according to the supply of water. The yield of *Aman* rice grown in the south of Faridpur is very heavy, says the Settlement Report, "but in the north of the district it is ordinarily much poorer and only becomes good when inundations come early and are widespread."

25. Jute comes next in importance to rice. As in the case of rice so for jute also ample water is necessary, largely governing the distribution of the plant and the character of the crop. Abundant water is also required for the retting of the fibre. "It is necessary to have water conveniently near," says the Settlement Report of the Faridpur district, "in which the jute can be steeped. This limits the amount of jute that can be grown in the north of the district considerably, but in the Madaripur subdivision the limit, owing to the abundance of small rivers and streams, has not been reached." The figures for jute cultivation in the province as a whole show that

64 per cent. is grown in Eastern Bengal, 26 per cent. in Northern Bengal and only 8 and 2 per cent. in Central and Western Bengal, respectively. And a comparison of data regarding the relative abundance of water indicates a close relationship between the supply of water and the yield of jute. Generally speaking also a rapid increase of population occurs in areas where jute is largely grown, whereas a reduction in the cultivation of jute is often followed by decline of population.

26. Among other minor changes in the flora of areas that are losing population, the disappearance of indigo and the reduction of mulberry may be mentioned. Indigo was formerly cultivated very widely, especially in Western and Central Bengal and in parts of Faridpur and Dacca; but it is no longer grown in any quantity and the indigo factories are all in ruins. Mulberry, too, has already undergone a very marked reduction in consequence of the decline in sericulture. Another change is the practical disappearance of cotton as a cultivated crop in the greater majority of the districts within the last century. But this latter change appears to have occurred long before the great increase of malaria and the rapid decline of population with which we are now concerned, and it is only therefore mentioned in passing.

27. Putting aside for a moment the increase of malaria and the loss of population, it will be seen that the other changes that have been noted as occurring among the fauna and the flora, respectively, of the decadent areas we have been discussing, point to the conclusion that a reduction in the water supply is the origin of the trouble. First of all there is the receding margin of cultivation. This is invariably associated with a lack of water. It is always the drier and more elevated lands that go out of cultivation. Then there is the increase of jungle which is largely confined to the relatively high banks of rivers and old village sites, showing that the type of vegetation is one which prefers a dry situation rather than a damp water-logged one. The tendency for *Aus* paddy to displace the *Aman* variety is also an indication of diminished moisture. The decreasing supply of fish affords further evidence of a lessened supply of water; and the increase of wild hog and other animals which has followed the increase of jungle points in the same direction. The only fact, therefore, which appears to militate against this view of the situation is the very great increase of malaria which has taken place along with these other changes, and which at first sight appears to preclude the possibility of a diminished supply of water being the cause of the trouble.

28. But we have only to recall two well-known facts in regard to malaria in order to realise that this difficulty is only an apparent one. Ever since Empedocles flooded the marshes surrounding Selinos in Sicily by a canal constructed for the purpose, and in this way freed the city from malaria, it has been known that swampy low-lying localities cease to be unhealthy when temporarily submerged; and in the old days flooding was often deliberately applied both in Italy and Holland for ameliorating malaria, with most excellent results. But while the flooding of swamps has long been resorted to for checking malaria the partial removal of water from a marshy area has always been regarded as a most dangerous proceeding, calculated to produce a serious intensification of the disease, this belief being justified by the numerous occasions in which the

reclamation of swamps has led to severe outbreaks of malaria. Three well-known instances of this kind are the case of the Grand Chartreuse Swamp in France, the low lands of Biensten and de Wonner in Holland and the Whittlesea Mere in England. Such outbreaks were formerly ascribed to miasma given off from the exposed bottom of the marsh. But now-a-days the accepted explanation is the great increase of anopheles that takes place when, by partial drying up, a large expanse of water is converted into many small shallow pools.

29. We see therefore that all the important changes which can be shown to have occurred in association with the loss of population that has taken place in so many areas in Bengal are consistent with a reduction in the water supply of the affected localities. This naturally prompts the question: Is there any direct evidence of such a diminution having taken place? In reply it may be stated that for many years the complaint has been general throughout the areas afflicted with severe malaria and undergoing depopulation, that water supplies have diminished. In 1867, the Revd. G. Schurr, of Kaspadanga in Nadia, reported in a letter to the Magistrate: "During the twenty years I have been in this district I have observed a gradual diminution of water supply in old tanks and *khals* as well as in the rivers."

30. The following year Dr. Sutherland observed of the same district: "The district is becoming more and more arid, tanks and other reservoirs of water dry up even before the hot weather, tanks full to overflowing in the rains rapidly dry up—facts which prove that there has been of late no increase or excess of moisture in the soil." Similar complaints have been put on record at various times in regard to every malarious district. As late as 1912, Mr. Bhola Nath Banarji, Executive Engineer in charge of the Special Drainage Division, while at work in Jessore reported: "If we draw a line from Pultia on the Ichamati to Jhikergacha on the Kabadak, the country lying to the north of this line may be generally taken as suffering from a scarcity of good drinking water." "It is reported," he adds, "that tanks in those parts do not hold water but dry up with the subsidence of the rivers." And he concludes by pointing out that most of the Jhenida subdivision and parts of Magura where people suffer from want of water are the most malarious parts of the district. Quite apart from general statements of the kind quoted, there is a certain amount of direct evidence pointing to the abnormal dryness of many localities that have long been suffering from increased malaria and depopulation. The Nadia Fever Commission, state that: "Observations in December of the water level in wells showed it to be from 15 to 24 feet from the general soil surface level in the west and north-west of the district." A few years earlier similar observations were placed on record for Birbhum district by Dr. Jackson, the Sanitary Commissioner. Recent observations in Burdwan, Nadia, Jessore, Pabna and Murshidabad have shown very similar results and have proved that, contrary to commonly accepted ideas, the areas in which the level of the subsoil water is specially low are far more malarious and unhealthy than those in which it approches within three to five feet of the ground surface. In Burdwan, which is one of the worst districts for malaria and depopulation, the mean level of the subsoil water,

taken in twenty-eight wells in different parts of the district, is 26 feet in the dry weather and 9 feet in the rains; whereas in healthy parts of Howrah, Dacca and Mymensingh it varies from 3 to 5 feet in the dry weather and is level with the ground surface in the rains. Apart from the moisture that is stored in the subsoil and which, as we have seen, is subject to very great variations in different parts of the province, the unhealthy, malarious and decadent tracts possess the lowest supply. The sources from which the country derives its supplies of water are the rainfall and the overflow from the rivers in the flood season. Although the rainfall fluctuates from year to year there is no reason to suppose that the average amount precipitated has undergone any marked diminution. On the other hand, there is plenty of evidence to show that the embankments that have been constructed along the margin of the rivers and for the purpose of roads and railways have had the effect of shutting out from the surface of the country a large amount of water which found access to it in former times. There are now many thousands of miles of embankments, which cover the country with a net-work extending in almost every direction. And there is no doubt that their effect has been to deprive the country of much of the moisture it formerly enjoyed. Time and again it has been suggested that these embankments have obstructed drainage and led to water-logging which has resulted in an increase of malaria. But repeated investigations have only served to show that, except in a very few places, the country within the influence of the embankments, instead of being damper than formerly, is actually much drier than it used to be. And in the light of the facts brought forward in this paper the explanation is a simple one. It is in the main to the construction of these embankments that we must look for the cause of the increase of malaria and the depopulation that has accompanied that increase. The decay of Kassimbazar, which has already been referred to, followed the construction of an embanked *pakka* road from Berhampur cantonment to Murshidabad city. That decay was, as we have seen, accompanied by a decline of agriculture and a change in the climate. And the same sequence of events can be traced in the history of almost every decadent tract in Bengal at the present time.

## APPENDIX II.

### Areas most in need of Anti-malarial Projects in Bengal.

What are the areas in Bengal most urgently in need of measures for the amelioration of malaria? This question can best be answered by reference to statistics relating to the prevalence of malaria in different districts and the census reports showing the growth or decline of population. These are safer guides than death-rates. Death-rates are largely influenced by high birth-rates and are also affected by the accuracy of the reporting agency, and are in consequence sometimes misleading. For example, some of the most unhealthy districts of Central and Western Bengal, whose death-rates always exceed their birth-rates, show a lower fever death-rate and total death-rate than healthier areas in Northern Bengal, which have birth-rates far above the average. Mortality rates do however, give valuable information which will be used in this note, but population figures and fever indices will be first referred to. Before dealing with individual districts, attention must be directed to the general condition of the four natural divisions of the province in these two respects.

2. *Expansion of population.*—The recent census has disclosed the following results regarding the expansion of population in the four natural divisions of Bengal, viz., Western Central, Northern and Eastern Bengal, the first three of which correspond to the respective administrative divisions of Burdwan, Presidency and Rajshahi, while Eastern Bengal includes the two administrative divisions of Dacca and Chittagong :—

| Natural division | Expansion of population | 1872—1921 |
|---|---|---|
| | Per cent | Per cent |
| Western Bengal (Burdwan Division) | − 5·1 | + 5·7 |
| Central „ (Presidency „ ) | − 0·1 | + 27·1 |
| Northern „ (Rajshahi „ ) | + 2·2 | + 28·8 |
| Eastern „ (Dacca and Chittagong Divisions) ... ... | + 8·0 | + 69·8 |

The Chittagong Hill Tracts are excluded from the latter, as they differ in every way from ordinary plains districts.

The figures for total expansion since 1872 suggest good health conditions in Eastern Bengal, unsatisfactory conditions in Central and Northern Bengal and very bad condition in Western Bengal and those for the last decade especially point to a very serious state of affairs in Western and Central Bengal.

3 The figures relating to the density of population per square mile in 1872 and 1921, respectively, are equally illuminating.—

| | Density of population | | Increase |
|---|---|---|---|
| | 1872. | 1921 | Total |
| Western Bengal ... | 545 | 570 | + 25 |
| Central „ ... | 424 | 539 | + 115 |
| Northern „ ... | 418 | 538 | + 120 |
| Eastern „ ... | 479 | 815 | + 336 |

The extraordinary development of the population in Eastern Bengal is due entirely to natural growth by excess of births over deaths; there are few towns and no important industries to attract

immigrants; this natural division also, as a matter of fact, has lost rather than gained by migration. This area affords therefore an example of normal expansion occurring in an agricultural population living under relatively favourable conditions. Conditions are obviously very different in the other divisions, all of which possess important industries which attract immigrants in large numbers. Western Bengal, for example, possesses coal and iron mills, etc., Central Bengal has a number of towns with many mills and factories and Northern Bengal includes nearly 200,000 acres under tea. Estimates of the gain by migration from these and other causes are difficult, but the excess of immigrants over emigrants in 1901 and 1911, *respectively*, was found to be about 6·3 and 7·4 per cent. of the population in Northern Bengal and 5·8 and 8·8 per cent. in *Central Bengal. Much of the expansion* in this latter division is *undoubtedly* due to immigrants to its many towns. Western Bengal, *on the other hand, lost nearly as much by emigration from certain of its rural areas as it gained* by immigration into its towns and industrial tracts. The conclusion to be drawn from the facts mentioned is that attention to the conditions affecting the growth of the rural population, especially in Western, Central and Northern Bengal, is urgently required.

4. *Decline in expansion of population.*—A moderate estimate of the normal rate of expansion for healthy populations in Bengal is 10 per 1,000 per annum or over 10 per cent. in a decade. We may assume, therefore, that the expansion of population since 1872 should everywhere have been roughly speaking at least 50 per cent. Examining the population expansion figures for the four natural divisions on this basis, we find that, whereas the total expansion of population in the 22,879 square miles of Eastern Bengal (excluding the Chittagong Hill Tracts) for the whole period has exceeded this estimate of normal healthy growth by as much as 19·8 per cent., the populations of Central and Northern Bengal, respectively, have shown on the other hand little more than half the estimated expansion; while in the course of 49 years, the population of Western Bengal has expanded by only 5·7 per cent. The figures for the last decade are even more significant. The population of Eastern Bengal has shown an expansion of approximately 8 per cent., a figure rather below the normal 10 per cent. and very much less than its former rate of growth; the population of Northern Bengal has expanded by less than a quarter of what might have been anticipated, and in both Central and Western Bengal there has been an actual decline.

The figures given below show, for each of the natural divisions, the deviations from the estimated normal rate of expansion for the whole period, 1872—1921, and for the last decade:—

*Deviation from estimated normal expansion of population.*

| | Period of 1872—1921 | Decade, 1911—1921 |
|---|---|---|
| | Per cent | Per cent. |
| Western Bengal ... ... | −44·3 | −15·1 |
| Central „ ... ... | −22·9 | −10·1 |
| Northern „ ... ... | −21·2 | −7·8 |
| Eastern „ ... ... | +19·8 | −2·0 |

5. What would the present populations of Western, Central and Northern Bengal, respectively, be if since 1872 they had expanded at the estimated normal rate of 10 per 1,000 per annum, or if they had grown by a total of 69·8 per cent. equal to the expansion which has actually occurred in Eastern Bengal? The table below gives the answers to these questions :—

| | Population in 1872. | Expansion at 50 per cent | Actual population, 1921. | Difference. | Expansion at 69·8 per cent. | Difference. |
|---|---|---|---|---|---|---|
| Western Bengal ... | 7,604,661 | 11,406,991 | 8,059,704 | - 3,367,287 | 12,912,714 | - 4,873,010 |
| Central ,, .. .. | 8,202,780 | 12 304,170 | 9,433,544 | - 2,870 626 | 13,381,424 | - 3,947,880 |
| Northern ,, .. .. | 8,045,432 | 12,068,148 | 10,358,303 | - 1,709,845 | 13,651,143 | - 3,302,840 |
| Eastern ,, ... | 10,980,504 | 16,470,756 | 18 650,139 | +2,179,383 | 18,650,139 | . .. |

From the figures given above, it will be seen that if the population in Western, Central and Northern Bengal had expanded at the estimated normal rate no less than 7,947,758 persons would in the aggregate have been added to the total actually found to be existing at the recent census; and that had the populations in these three divisions increased in the same proportion as in Eastern Bengal, the increase would have added 12,123,730 persons to the existing number, thus making the total population of the four divisions 58,605,420 in place of the actual figure of 46,481,690 Why has this expansion not occurred?

6. The commonest explanation offered is the prevalence of malaria; and colour is given to this view by available data regarding the relative distribution and intensity of the disease in the different natural divisions. Malaria may check the growth of even a prosperous population by increasing the death-rate and reducing the birth-rate. And when malaria is associated with deficiency of the available food supply, healthy expansion of population becomes absolutely impossible. The food supply of a population is governed by the agricultural production. The statistics relating to agriculture in Bengal show that production varies greatly in the four natural divisions. In Eastern Bengal generally, agriculture is prospering, but in the areas in which malaria is prevalent and normal expansion of population has been checked, agriculture appears to have suffered relative decline.

7. On comparing the figures relating to the total cultivable area and the net area normally cropped in the various divisions with those of the respective populations, we get the results noted below per head of the population :—

*Acre per head of population*

| | Cultivable | Net cropped |
|---|---|---|
| Western Bengal ... | 0·87 | 0·54 |
| Central ,, ... | 0·69 | 0·40 |
| Northern ,, ... | 0·90 | 0·64 |
| Eastern ,, ... | 0·54 | 0·48 |

These figures point to a vast difference in the relative fertility of the various divisions. Eastern Bengal is obviously the most fertile area, Northern Bengal comes second with a relative fertility 80 per cent. that of Eastern Bengal, and land in Western Bengal and Central Bengal appears in the ratio of 70 and 65 per cent. when compared with the same standard. In other words, an area of a size sufficient to support a population of 100 persons in Eastern Bengal will only serve for 80 in Northern Bengal, 70 in Western Bengal and 65 in Central Bengal. As a matter of fact, the number given for the two latter divisions is an over estimate, because it makes no allowance for the much larger proportion of the population in these two divisions supported by industry rather than agriculture. Further light is thrown on this question of relative fertility and its effect on the agricultural prosperity of the different divisions by statistics relating to the approximate proportion of the cultivable area cultivated, that lying waste and that occupied by current fallows.

8. It will be seen from the figures given below how much more favourable conditions appear in Eastern Bengal than in the other natural divisions :—

| | Percentage cultivable area cultivated | Percentage cultivable waste | Percentage current fallows |
|---|---|---|---|
| | Per cent | Per cent | Per cent. |
| Western Bengal ... | 61 | 26 | 13 |
| Central ,, ... | 58 | 18 | 24 |
| Northern ,, ... | 71 | 14 | 15 |
| Eastern ,, .. | 90 | 7 | 3 |

Western Bengal is apparently only just over two-thirds and Central Bengal under two-thirds as well cultivated as Eastern Bengal and in Northern Bengal only 4 acres are cropped against every 5 cultivated in Eastern Bengal. Again for every acre of cultivable land lying waste in Eastern Bengal there are in proportion 2 acres lying uncultivated in Northern Bengal, 2½ acres in Central Bengal and 3·7 acres in Western Bengal. As regards land lying fallow, it would appear to be in proportion 4·3 times as common in Western Bengal as in Eastern Bengal, five times as common in Northern Bengal and eight times as common in Central Bengal. In connexion with the question of fallows it must be remembered that the term as ordinarily applied in Bengal is really a misnomer. The fallows of Europe and American farming consist in land that is ploughed but on which no crop is actually sown. Whereas in Bengal current fallow usually means land which is temporarily out of cultivation in contradistinction to waste land which is permanently uncultivated.

9. To those familiar with the relation between lack of cultivation and growth of useless vegetation and the presence of malaria, these facts have a special significance. It may be asked why do not the people in Western, Central and Northern Bengal cultivate a larger proportion of the land than they do? The answer to this question lies at the root of the problem of malaria prevention in Bengal, and before dealing with it attention must be directed to a few more figures relating to the agricultural conditions existing in the various

divisions. The figures noted below refer to the average deviation from the estimated normal production of rice during the period 1901—1911 and for the year 1918 :—

| | Percentage crop deficiency. | |
|---|---|---|
| | 1901-11. | 1918. |
| Western Bengal ... ... | -22 | -38 |
| Central „ ... ... | -21 | -34 |
| Northern „ ... ... | -12 | -49 |
| Eastern „ ... ... | -7 | -27 |

The figures that have been quoted show how very much less favourable are agricultural conditions in Western, Central and Northern Bengal than in Eastern Bengal.

10. What is the explanation of the remarkable difference in the agricultural prosperity of the four natural divisions? The main causes of the disparity observable may be summed up in three words : (1) water, (2) manure and (3) labour. The area that is most prosperous is the one enjoying the largest water-supply, receiving the greatest amount of manure and in which the population, hence the labour efficiency, is least affected by malaria. And conversely, the least prosperous areas are those where the majority of the population is subject to recurring attacks of malarial fever.

11. *Water-supply.*—In agriculture, water-supply is of supreme importance. "It is only when we fully appreciate the important role played by water in crop production that we are in position to see how necessary to large yields is the right amount of water at the right time", says King. Water not only renders cultivation possible but largely governs the resulting outturn. "Experience as well as numerous rigorous experiments have shown," says Hilgard, "that under ordinary conditions of culture and within limits varying for different soils and crops, production is almost directly proportioned to the water-supply during the period of active vegetation." Turning to the following rainfall statistics of the province, we find that Eastern Bengal, where agriculture is most flourishing, where population has grown most rapidly and where malaria is least prevalent, enjoys a much heavier rainfall than the other natural divisions. Whereas Western and Central Bengal, where malaria is intense, population decadent, and agriculture is in a parlous condition, receive the lowest rainfall :—

RAINFALL OF BENGAL.

*Normal average of natural divisions.*

| | Inches |
|---|---|
| Western Bengal ... ... ... | 57·00 |
| Central „ ... ... ... | 61·02 |
| Northern „ ... ... ... | 81·77 |
| Eastern „ ... ... ... | 94·85 |

The normal average rainfall of Eastern Bengal is about 60 per cent. greater than that of Western and Central Bengal. Apart from any other factor this alone is sufficient to secure an immense

superiority in agricultural production. The cultural experiments of Tucker and Von Seelhorst have shown for example that an increase of less than 60 per cent. in the moisture provided raised the yield of oats by 65 per cent on unmanured and 97 per cent. on manured soil, respectively. An abundant supply of water is even more essential in the case of wet crops. Take the case of rice. A former Director of Agriculture in a special report on the cultivation of rice emphasizes its need of abundant water in the following words:—"Compared with the advantages of a proper supply of water all other questions in its cultivation, namely, the quality of the seed used, the nature of the soil on which it is grown, the manures applied and the mode of cultivation adopted are things of very minor importance." If this view is correct, Eastern Bengal, which enjoys the heaviest rainfall, should produce the best rice crops; and what do we find? "The yield per acre of cleaned rice is estimated at 11·02 cwts. for winter rice and 7·34 cwts. for the early and spring crops", says the Imperial Gazetteer. And then it qualifies the statement with the significant remark: "In the rich rice swamps of Eastern Bengal, the return is at least half as much again." Local rainfall is not the only source of the water supplied to the land in Eastern Bengal. Much of this favoured area is subject to natural irrigation with river water. "It is the height and duration of the flood, even more than the local rainfall, which decides whether the harvest in Dacca will be good or bad", writes Mr. B. C. Allen, I.C.S. "These floods serve a double purpose for they not only supply the crop with the moisture it requires, but they restore fertility to the soil by the rich deposits of silt which they bring down." The process of natural irrigation by river water, referred to in the above passage, increases the yield partly as a result of the abundance of moisture supplied to the crops and partly owing to the manurial value of the silt, which the river waters contain. "The gneissic laterite and old alluvial soils are alike mainly dependent upon artificial manures to maintain their fertility." Whereas the recent alluvium is periodically fertilized by fresh deposits of silt from the overflowing rivers. "The latter process," adds the Census Report, "is most active in Eastern Bengal in the deltas of the Ganges and Brahmaputra, whose waters possess the fertilizing properties of the Nile." Nile silt has a high manurial value. "At soluble commercial fertilizer rates," says Foaden, "the value of the mud deposited on an acre is approximately equal to £ 1·50."

There is a little question that inundation by the silt-laden waters of the rivers conduces very greatly to the agricultural prosperity of Eastern Bengal and the portions of Northern Bengal, which also enjoy this advantage. It is these areas in particular which provide the bulk of the jute harvests upon which so much of the prosperity of Bengal depends. Silt-laden water possesses a further advantage: it checks the growth of weeds in the fields and in the drainage channels; and at the same time it reduces the breeding of anopheles mosquitoes owing to the fact that for some unexplained reason the larvæ of these insects appear to be unable to flourish in silty water.

12. *Labour efficiency.*—It is not easy to form an estimate of the relative efficiency of agricultural labour in different parts of the province. But the great prevalence of malaria in many areas cannot be without its effect. Malarial fever, as is well known, tends to relapse again and again, and it is therefore a potent cause of

sickness and disability. Over-exertion and fatigue are potent factors also in determining relapses in the case of infected individuals. In many parts of Western and Central Bengal, over 90 per cent. of the rural population is probably infected with malaria, and in these circumstances the loss of working efficiency must sometimes be very great indeed, especially at the time of harvesting the winter rice crop. The average fever indices of the four natural divisions, which are cited in a succeeding paragraph, show a great disparity in favour of Eastern Bengal. In connection with labour efficiency, the fact that the twice-cropped area is far greater where there is least malaria is possibly not without some significance. With these facts before us, we can begin to grasp the causes underlying the more rapid growth of population in Eastern Bengal when compared with the other natural divisions. And when we have considered the figures relating to the relative prevalence of malaria in the different areas, we shall begin to understand the special character of the remedies most likely to effect the amelioration of malaria in the parts of the province specially subject to the disease.

| Natural Divisions | Normal twice-cropped area | Percentage of cultivable area |
|---|---|---|
| Western Bengal ... | 379,000 acres | 5·3 |
| Central „ ... | 784,500 „ | 12·3 |
| Northern „ ... | 1,649,100 „ | 17·0 |
| Eastern „ ... | 2,046,700 „ | 20·0 |

13. *The relative prevalence of malaria.*—The fever indices given below also show that malaria is far more pravalent in Western, Central and Northern Bengal than in Eastern Bengal :—

| | 1868 | 1912 | 1920 |
|---|---|---|---|
| | Per cent. | Per cent. | Per cent. |
| Western Bengal ... | 21·9 | 40·9 | 51·7 |
| Central „ ... | 17·3 | 32·3 | 44·9 |
| Northern „ ... | 22·3 | 23·7 | 33·5 |
| Eastern „ ... | 9·3 | 7·5 | 14·0 |

What is the cause of the disparity ? Before attempting to answer this question, we must briefly glance at the salient facts relating to the disease. Malaria is caused by a small animal parasite inocculated into the blood of men through the bite of anopheles mosquitoes. These mosquitoes are not naturally infected with malaria but have first to obtain the parasites by sucking the blood of human beings already infected. Now mosquitoes require water in which to breed ; the adult insects cannot exist for many days in a dry atmosphere ; and the malaria parasite also requires a certain temperature to enable it to develop in the body of an anopheles mosquito. Before malaria can become prevalent in any locality, or at any given season therefore certain conditions must be fulfilled : (*a*) *firstly*, infected human beings must be present ; (*b*) *secondly*, suitable collections of surface water for the breeding of anopheles in sufficient numbers must

*exist; (c) thirdly,* the humidity of the atmosphere must be favourable to the longivity of anopheles, and *(d) fourthly,* the temperature of the atmosphere must be high enough to allow the parasite to develop. Although *(a)* and *(b)* often occur at every season of the year, malaria cannot spread unless the conditions *(c)* and *(d)* are satisfied also, which usually occurs only during the wet season. Malaria naturally tends to increase therefore during the wet season, and the majority of new infections are as a rule contracted during this period. But owing to the variable incubation period, which may extend to several weeks, and the fact that the sudden onset of colder days and nights tends to determine attacks of fever in those who have become infected and bring out relapses in persons who harbour the parasite, it often happens that the greatest number of actual cases of malarial fever occurs after the end of the rains just at the beginning of the cold season. Thus, it often happens that when cases of malaria are most numerous the conditions actually responsible for the presence of the infection have for the moment passed away with the change of the season. The greatest mortality from malaria is usually met with at a still later period owing to the fact that persons who are chronic cachetics fall victims to malaria in far greater numbers than do those who are suffering from the initial acute attack that usually follows first infection. Malaria, as we have seen, is chiefly propagated during the wet season, as a direct result of the climatic conditions and the great increase of facilities for the breeding of anopheles, which ordinarily occur at this time of the year, owing to the multiplication of collections of surface water. But in certain circumstances, to which special reference will be made subsequently, an increase of surface water instead of favouring the breeding of anopheles, tends to diminish their number. The nature of collections of water in which anopheles breed, their size, the character of the water and the temperature to which this water is raised by the heat of sun, all have an important bearing on the multiplication of anopheles. Small collections of water in pools, drains and streams, which possess a large proportion of weedy edge, are most favourable to anopheles larvæ, owing partly to the amount of shelter and food provided and also because the temperature of the water remains relatively low. Large collections of water possess a relatively smaller ratio of dangerous edge to surface and tend to have a higher temperature. Exposure to the sun may render them very unfavourable for mosquito larvæ while muddy river water appears to be inimical to anopheles larvæ. Now the cultivation of rice is carried on during the rainy season, which coincides with the periods when anopheles mosquitoes ordinarily tend to multiply, and the transmission of malaria infection therefore becomes most active. In the circumstances best suited to the growth of rice in Bengal, it might be thought that the amelioration of malaria was a hopeless undertaking, because it is often assumed that increasing the water must also increase the mosquitoes and the resultant malaria. But, as we have seen, there is a point beyond which an increase of surface water instead of being favourable to anopheles larvæ becomes unfavourable to them, and results in their rapid destruction. This explains the apparent anomaly that those districts, which have the highest rainfall and possess the greatest amount of surface water during the cultivating season, are the areas where malaria is least prevalent, where agriculture is in a most flourishing condition and

where the rural populations have multiplied at a rate far in excess of what might have been thought possible. An ample supply of surface moisture therefore confers a double benefit, improving the yield of the crops and protecting the population from malaria, and these benefits are most conspicuous in the areas liable to inundation with silt-laden river water. Although malaria is chiefly propagated in the wet season, its ravages become most apparent when that season is over. The anopheles have by this time practically finished their season's work, and no attempt to reduce their numbers can therefore have much effect. It follows that when malaria is causing the greatest amount of sickness and mortality the only remedy that can prove immediately useful is the relief of the sufferers by adequate treatment of the disease. If sufficiently intensive to cure the individual and sufficiently extensive to improve the general health of the community the remedial treatment of malaria by quinine may effect a considerable improvement in the conditions of a limited population. But it offers little hope of effecting a permanent amelioration of malaria in a locality, because it leaves conditions relating to the breeding of anopheles (which are those primarily responsible for the existence of the disease) absolutely unaltered. The aim of the sanitarian, therefore, must be to change or control the environment, so that conditions during the season when malaria is actually propagated are made as unsuitable as possible for the breeding of anopheles mosquitoes, while at the same time the human population is benefited directly and indirectly by the measures adopted.

14. *Western Bengal.*—We are now in a position to examine the data relating to individual districts in Western Bengal with a view to discovering the areas in that division most urgently in need of remedial measures. The expansion of population in the districts of this area between 1872—1921 and 1911—1921, respectively, are given below :—

| | 1872—1921. | 1911—1921 |
|---|---|---|
| Burdwan ... | ... - 3·1 | - 6·4 |
| Birbhum ... | ... - 0·5 | - 9·5 |
| Bankura ... | ... + 5·3 | - 10·5 |
| Midnapur | ... + 4·6 | - 5·9 |
| Hooghly ... | ... - 3·6 | - 1·1 |
| Howrah ... | ... - 56·2 | + 5·3 |

The figures show that, since 1872, there has been an absolute decline of population in three districts and that during the last decade the process of depopulation has extended and accentuated, five out of the six districts being largely decadent. The area of the decadent thanas aggregated 5,339 square miles in 1911, and there is little doubt that the recent census will show a considerable increase when the figures become available. Some idea of the waste of human life that has occurred in this division during the past 50 years may be obtained by an estimate of the deviation that has taken place

from the normal rate of increase at 10 per 1,000 per annum. The following figures give the districts arranged in order to show the greatest loss of natural increase :—

| | Since 1872 Per cent. |
|---|---|
| Hooghly ... ... ... | - 53·6 |
| Burdwan ... ... ... | - 53·1 |
| Birbhum ... ... ... | - 50·5 |
| Midnapur ... ... ... | - 45·4 |
| Bankura ... ... ... | - 44·7 |
| Howrah ... ... ... | + 6·2 |

These figures show that the Howrah district is the only one that has experienced a satisfactory growth of population. Part of this growth is owing to gain by immigration. The remaining districts are in a parlous condition, and it is obvious from the figures of the last census that radical measures of relief are required in every one of them.

15. *Fever indices in Western Bengal.*—The fever indices noted below show that with the exception of Howrah every district is seriously affected with malaria :—

| | 1920 | 1921. | Mean |
|---|---|---|---|
| Burdwan ... ... | 62·8 | 54·4 | 58·6 |
| Hooghly ... ... | 56·4 | 36·8 | 47·6 |
| Bankura ... ... | 55·1 | 24·7 | 39·9 |
| Birbhum ... ... | 54·0 | 39·1 | 46·6 |
| Midnapur ... ... | 40·2 | 31·6 | 35·9 |
| Howrah ... ... | 20·1 | 23·6 | 21·9 |

The disease is, as a whole, less intense in Midnpore and Howrah than in the remaining four districts. There are considerable variations in the local intensity of the disease in the different districts. The data available regarding the fever indices of a number of different localities in each district suggests the following classification for each district :—

| | Intensely malarious | Malarious | Slightly malarious |
|---|---|---|---|
| | Per cent. | Per cent. | Per cent. |
| Burdwan ... ... | 72·4 | 24·0 | 3·4 |
| Hooghly ... ... | 47·8 | 39·1 | 13·0 |
| Bankura ... ... | 46·1 | 38·4 | 15·3 |
| Birbhum ... ... | 31·2 | 68·0 | 0·0 |
| Midnapur ... | 26·9 | 46·1 | 26·9 |
| Howrah ... ... | 0·0 | 50·0 | 50·0 |

The healthiest portion of Burdwan is situated in the Asansol subdivision in the extreme west of the district ; in Hooghly, the low-lying portions of the Singur and Chanditola thanas are relatively free of malaria ; in Bankura the high undulating tract in the west of the district is the most healthy area ; in Midnapur, the low-lying Contai and Tamluk subdivisions contain the least malarious localities ; and in Howrah, the southern half of the district is less malarious than the portion to the north-west.

*Fever death-rates.*—The following mean fever-death rates of the ten years 1911 to 1920 emphasize the extreme unhealthiness of every district except Howrah, but show that Midnapur is not yet quite so bad as the other four districts; this is owing to the fact that nearly a third of the district is still relatively healthy :—

| | *Mean of 1911-20.* |
|---|---|
| Birbhum ... ... ... | 34·5 |
| Burdwan ... ... ... | 28·9 |
| Bankura ... ... ... | 26·2 |
| Hooghly ... ... ... | 24·3 |
| Midnapur ... .. ... | 21·2 |
| Howrah ... ... ... | 11·9 |

16. *Conclusion regarding the Burdwan Division.*—(1) The need of remedial measures in the majority of the districts of the Burdwan Division is obvious from the facts stated above.

(2) Work is urgently required in at least five out of the six districts.

(3) Hooghly and Burdwan have been longest unhealthy and have lost in the aggregate the greatest population.

(4) Birbhum and Bankura have both suffered very severely from malaria and loss of population in recent years and are rapidly approaching the condition of Burdwan and Hooghly.

(5) A large portion of Midnapur is retrogrado.

(6) Howrah district is at present far less unhealthy than the others.

17. *Central Bengal.*—The following statement gives the expansion of population in the districts of Central Bengal for the total period 1872—1921 and the decade 1911-21 :—

| | 1872—1921. | 1911—1921. |
|---|---|---|
| 24-Parganas ... ... | +65·0 | +7·8 |
| Nadia ... ... | − 0·3 | −8·1 |
| Murshidabad ... ... | + 2·5 | −9·3 |
| Jessore ... ... | +19·7 | −1·2 |
| Khulna ... ... | +39·5 | +6·8 |

Nadia district has experienced an absolute decline of population as compared with 1872, whereas all the other districts have shown some increase, though that in Murshidabad is insignificant. During the last decade, three districts, Nadia, Murshidabad and Jessore, have lost population, the two first very considerably. 24-Parganas and Khulna, which show the greatest aggregate increase, are the only districts that have gained population in the last decade Jessore in which the aggregate gain of population since 1872 is about half that of Khulna, has lost ground slightly since 1911. The decadent thanas in the division at the time of the census in 1911 covered an area of 5,262 square miles, situated almost wholly in Nadia, Murshidabad and Jessore. At the time Jessore had in proportion the largest area decadent, but there is little question that precedence in this respect must now be given to Nadia and Murshidabad. The deviation from the estimated normal rate of increase of population for each district

during the past 49 years may be seen by reference to the figures noted below which are arranged in the order of the greatest proportional loss :—

| | 1872—1921. | 1911—1921. |
|---|---|---|
| | Per cent. | Per cent. |
| Nadia ... | -50·3 | -16·1 |
| Murshidabad ... | -47·5 | -19·3 |
| Jessore ... | -30·3 | -11·2 |
| Khulna ... | -10·5 | - 3·2 |
| 24-Parganas ... | +15·0 | - 2·2 |

It will be seen that, with the exception of the 24-Parganas, where the growth of population has exceeded the normal rate of increase, every district has lost ground ; the two most decadent districts being Nadia and Murshidabad, while Jessore comes midway between these two districts and Khulna, where the deviation from the normal has been relatively small. These figures suggest the need of remedial measures in the first three districts named, the need being *especially urgent in Nadia and Murshidabad.*

18. *Fever indices.*—The fever indices given below relating to various districts of Central Bengal show that malaria is widely prevalent, but that while the disease is intense in Nadia, Murshidabad and Jessore, it is less prevalant in the 24-Parganas :—

| | 1920 | 1912. | Mean. |
|---|---|---|---|
| 24-Parganas ... | 35·4 | 29·4 | 32·4 |
| Nadia ... ... | 53·9 | 36·7 | 45·3 |
| Murshidabad ... | 57·4 | 33·9 | 45·7 |
| Jessore ... ... | 45·8 | 42·0 | 43·9 |
| Khulna ... ... | 37·2 | 28·1 | 32·7 |

The examination of different localities in each district gives the following results :—

| | Intensely malarious | Malarious | Slightly malarious. |
|---|---|---|---|
| | Per cent. | Per cent. | Per cent. |
| Murshidabad ... | 50·0 | 45·8 | 4·1 |
| Nadia ... ... | 36·0 | 60·0 | 4·0 |
| Jessore ... | 15·0 | 85·0 | 0·0 |
| 24-Parganas | 3·7 | 62·9 | 23·3 |
| Khulna ... | 0·0 | 70·8 | 29·1 |

These figures show that half of Murshidabad, more than a third of Nadia and about a sixth of the localities in Jessore are intensely malarious. In Murshidabad and Nadia, a few localities near live rivers are still relatively healthy. In Khulna, considerable proportion of the low-lying Sundarbans tracts are healthy and in the 24-Parganas the Diamond Harbour subdivision is, as a whole, relatively free of malaria.

19. *Fever death-rates.*—The following mean fever death-rates of the decade 1911-20 show that Murshidabad and Nadia have been specially seriously affected, and so far support the conclusions arrived at by a consideration of the population figures and the fever Indices :—

*Mean 1911-20.*

| | Per thousand. |
|---|---|
| Murshidabad ... ... ... | 34·0 |
| Nadia ... ... ... | 32·8 |
| Jessore ... ... ... | 24·9 |
| Khulna ... ... ... | 19·0 |
| 24-Parganas ... ... ... | 16·3 |

The Drianage Committee for the Presidency Division in 1906-07 put forward the view that the districts of Jessore and Nadia were the most malarious in the division, although they mentioned that there was a tract of some 1,919 square miles in the Murshidabad district in which the disease was of marked virulence. But the facts that have been brought forward in this note seem to show that Murshidabad, at least in recent years, has suffered as severely as Nadia and that these two districts are in a worse condition than Jessore, which has long been notorious for its unhealthy climate. It would appear, therefore, that while every district in Central Bengal requires attention, efforts should be concentrated especially upon Murshidabad, Nadia and Jessore, and that if any order of precedence be given it should be assigned to the districts in the order named.

20. *Northern Bengal.*—The following statement, which gives the percentage increase of population for each district of Northern Bengal since 1872 and during the decade 1911—1921, shows that conditions in this area compare favourably with those of Western and Central Bengal. But they are not wholly satisfactory. No district, it is true, has suffered an actual decline of population since 1872, but the increase has been very small in Rajshahi and in Pabna ; Rangpur and Dinajpur also indicate very slow expansion. The figures for the last decade also indicate a loss in two districts, Pabna and Malda, and an insignificant increase in Rajshahi and Dinajpur, while in no district has the increase exceeded the very moderate rate of 6·6 per cent.

*Population expansion.*

| | 1872—1921. | 1911—1921 |
|---|---|---|
| Rajshahi ... ... | + 4·8 | +0·7 |
| Dinajpur ... ... | + 18·9 | +0·8 |
| Jaipaiguri ... ... | +124·8 | +3·8 |
| Darjeeling ... ... | +196·2 | +6·0 |
| Rangpur ... ... | + 16·3 | +5·0 |
| Bogra ... ... | + 63·5 | +6·6 |
| Pabna ... ... | + 15·1 | −2·4 |
| Malda ... ... | + 47·3 | −0·5 |

21. If we examine the deviation from the estimated normal rate of growth since 1872, Rajshahi, Pabna, Rangpur and Dinajpur appear to have suffered severe checks of normal expansion. In the case of Malda also, where population has developed at a rate closely approaching the normal, it is clear from the small loss reported at the last census that the district is now on the down grade. Bogra has more than exceeded the natural rate of growth and in Jalpaiguri and Darjeling the expansion has been extraordinary. In the former district, population has on the average grown at 2½ times the normal rate and in the latter at almost exactly four times this figure.

| | | |
|---|---|---|
| Rajshahi ... ... | - 45·2 | - 9·3 |
| Pabna ... ... | - 34·9 | - 12·6 |
| Rangpur ... ... | - 33·7 | - 5·0 |
| Dinajpur ... ... | - 31·1 | - 9·2 |
| Malda ... ... | - 2·7 | - 10·5 |
| Bogra ... ... | - 12·5 | - 3·4 |
| Jalpaiguri ... ... | - 14·8 | - 6·2 |
| Darjeeling ... ... | - 116·2 | - 4·0 |

22. The fever indices of the various districts, noted below, throw a rather different light upon the health conditions of North Bengal —

*Fever Indices in Northern Bengal.*

| | 1920 | 1912 | Mean |
|---|---|---|---|
| Rajshahi ... ... | 29·7 | 28·6 | 29·2 |
| Dinajpur ... ... | 38·4 | 33·1 | 35·8 |
| Jalpaiguri ... ... | 38·1 | 21·2 | 29·7 |
| Darjeeling ... ... | 20·2 | 23·0 | 21·6 |
| Rangpur ... ... | 28·0 | 17·1 | 22·6 |
| Bogra ... ... | 42·0 | 16·6 | 29·3 |
| Pabna ... ... | 37·8 | 23·0 | 30·4 |
| Malda ... ... | 42·4 | 39·4 | 40·9 |

In 1920 Malda, Bogra, Dinajpur, Jalpaiguri and Pabna were the most feverish, whereas eight years earlier Bogra was relatively less malarious and Malda, Dinajpur and Rajshahi headed the list.

Further information as to the relative intensity of malaria in different localities in the various districts is given below :—

| | Intensely malarious | Malarious. | Slightly malarious |
|---|---|---|---|
| | Per cent | Per cent | Per cent. |
| Jalpaiguri ... ... | 27·2 | 63·6 | 9·0 |
| Malda ... ... | 23·5 | 76·4 | 0·0 |
| Bogra ... ... | 16·6 | 77·7 | 5·5 |
| Pabna ... ... | 14·2 | 71·4 | 14·2 |
| Dinajpur ... ... | 15·0 | 82·6 | 4·3 |
| Darjeeling ... ... | 9·0 | 54·5 | 36·3 |
| Rangpur ... ... | 7 5 | 52·5 | 40·0 |
| Rajshahi ... ... | 0·0 | 77·7 | 23·2 |

23. *Fever death-rates.*—The main fever death-rates of the decade 1911 –1920 show Dinajpur, Malda, Rajshahi and Jalpaiguri to be more unhealthy than the remaining districts, while Pabna is low down on the list. It must be remembered that these rates are all calculated on the census populations of 1911 and as a result the fever death-rates for Jalpaiguri, Rangpur, Darjeeling and Bogra appear too high and that for Pabna too low. In so far as the figures appear to represent Pabna as more healthy than Malda and Rangpur, they are probably misleading. The tendency in this division as a whole is to find the largest proportion of death recorded under the head of "Fever" and the fewest under "Other causes," hence the fever death-rates are swelled to abnormal proportions.

| | Mean. |
|---|---|
| Dinajpur ... ... ... | 34·3 |
| Malda ... ... ... | 31·3 |
| Rajshahi ... ... ... | 31·2 |
| Jalpiguri ... ... ... | 30·7 |
| Rangpur ... ... ... | 29·4 |
| Darjeeling ... ... ... | 28·8 |
| Pabna ... ... ... | 27·4 |
| Bogra ... ... ... | 24·3 |

24. *Eastern Bengal.*—Reference has already been made to the extraordinary expansion of population in Eastern Bengal, and the figures for the individual districts are merely given below for the sake of comparison with those of the other divisions :—

| | | |
|---|---|---|
| Dacca ... ... | + 76·0 | + 8·5 |
| Mymensingh ... ... | +105 2 | + 6·8 |
| Faridpur ... ... | + 44·3 | + 4·8 |
| Bakarganj ... ... | + 39·0 | + 8·0 |
| Chittagong ... ... | + 42·8 | + 6·8 |
| Tippera ... ... | + 89·4 | + 9·4 |
| Noakhali ... ... | + 74·9 | +12·9 |

It will be seen at once that this natural division exhibits a very marked contrast to the other three. The causes of this difference will be discussed later; meanwhile attention may

be directed to the figures relating to deviation from the estimated normal expansion in the last 49 years. In four districts, the actual expansion is in excess of this, a fact which proves conclusively that the standard assumed is not too high. In three districts, the rate of expansion is below the normal. In the case of Bakarganj, the fact that the total expansion since 1872 has not reached the normal estimate of 50 per cent., is largely due to the great storm wave of 1876, which directly or indirectly caused enormous loss of life. In the case of Chittagong, emigration is a very constant and heavy factor. For example, in 1877 emigrants exceeded immigrants by 8 per cent. and in 1911 by 5 per cent. In the case of Faridpur, the northern half of the district is decadent and has long been suffering depopulation from causes similar to those affecting the neighbouring districts of Nadia and Jessore. This part of the district requires measures for the amelioration of malaria. The figures for the last decade show that only one district, Noakhali, has actually exceeded the estimated normal rate of growth but in the case of Tippera the deviation is very small. As we shall see by the fever indices referred to below, these two districts are at present less affected by malaria than any other part of the province :—

| | 1873—1921 Per cent | 1911 21 Per cent |
|---|---|---|
| Bakarganj ... ... | −11·0 | −2·0 |
| Chittagong ... ... | − 7·2 | −3·2 |
| Faridpur ... ... | − 5·7 | −5·2 |
| Dacca ... ... | +16·0 | −1·5 |
| Noakhali ... ... | +24·9 | +2 9 |
| Tippera ... ... | +39·4 | −0 6 |
| Mymensingh ... ... | +55·2 | −3·2 |

*Fever Indices.*

| | 1920 | 1912 | Mean |
|---|---|---|---|
| Dacca ... | 16·4 | 7·1 | 11·7 |
| Mymensingh ... | 13·0 | 5·3 | 9·1 |
| Faridpur ... | 26·9 | 16·9 | 21·9 |
| Bakarganj ... | 13·9 | 10·6 | 12·2 |
| Chittagong ... | 20 2 | 6·8 | 13·5 |
| Tippera ... | 7·6 | 4·2 | 5·9 |
| Noakhali ... | 11·6 | 4·4 | 8·0 |

The figures relating to incidence of fever show that Faridpur is more seriously affected with malaria than any other district of Eastern Bengal. But the data relating to localities, given below, throws more light upon the relative distribution of the disease in this division :—

| | Intensely malarious | Malarious. Per cent. | Slightly-affected malarious Per cent. |
|---|---|---|---|
| Faridpur ... | 0 | 42·8 | 57·1 |
| Dacca ... | 0 | 20·4 | 79·5 |
| Chittagong ... | 0 | 20·0 | 80·0 |
| Mymensingh ... | 0 | 11·6 | 88·3 |
| Bakarganj ... | 0 | 8·5 | 91·4 |
| Noakhali ... | 0 | 5·2 | 94·7 |
| Tippera ... | 0 | 0 | 100 |

These figures accord with what we know about Faridpur, viz., that about half the district is malarious, although as a whole the disease has not yet reached the degree of severity met with in Western and Central Bengal. In Dacca, about a fifth of the district is malarious, the disease being most prevalent in parts of the Manikganj subdivision and Madhupur Jungle Tracts. In Chittagong, portions of the district are malarious ; in Mymensingh, parts of Tangail and Jamalpur sub divisions are specially affected. In the other districts the malarious localities are few and far between. Altogether Eastern Bengal offers a striking contrast to the other parts of the province in respect to malaria, the only areas calling for immediate attention being those named above ; and even in their case although certain localities are no doubt very badly affected, the problem of amelioration does not present the same urgent need of solution as that is offered by the districts in Central and Western Bengal. On the other hand, Eastern Bengal has its own special need, viz., malaria prevention. In its way this is as important as malaria amelioration. Signs are apparent pointing to the threatened extension of malaria eastward, and precautions are necessary if the tragedy of Western and Central Bengal is not to be repeated. But this question does not concern us at the moment and must be made the subject matter of a further note.

25. *Conclusions as to districts in which work must be undertaken.*—Having examined figures relating to the various districts of the province we can state that in four, Burdwan, Birbhum, Hooghly and Nadia, where population has declined below what it was in 1872, measures of amelioration must be undertaken without further delay. And if this is admitted, the districts of Bankura, Murshidabad, Midnapur, Pabna, Jessore and Malda, which have lost population since 1921, must be included in the list. But this selection would exclude districts, such as Rajshahi and Dinajpur, which have long been suffering from malaria, and Bogra, in

which the disease appears to have recently undergone great intensification. The best method of coming to a conclusion is to arrange the data for all districts in the order of intensity :—

| Deviation from normal expansion, 1873—1921. | | Deviation from normal expansion, 1911—1922. | | Mean fever indices. | | Percentage localities intensely malarious. | |
|---|---|---|---|---|---|---|---|
| | Per cent. | | Per cent | | Per cent. | | Per cent |
| Hooghly | −53·6 | Bankura | −20·5 | Burdwan | 58·6 | Burdwan | 72·4 |
| Burdwan | −53·1 | Birbhum | −19·5 | Hooghly | 47·6 | Murshidabad | 50·0 |
| Birbhum | −50·5 | Murshidabad | −19·3 | Birbhum | 46·6 | Hooghly | 47·8 |
| Nadia | −50·8 | Nadia | −18·1 | Murshidabad | 45·7 | Bankura | 46·1 |
| Murshidabad | −47·5 | Burdwan | −16·4 | Nadia | 45·3 | Nadia | 34·0 |
| Midnapur | −45·4 | Midnapur | −15·7 | Jessore | 43·9 | Birbhum | 31·2 |
| Rajshahi | −45·2 | Pabna | −12·4 | Malda | 40·9 | Jalpaiguri | 27·2 |
| Bankura | −44·7 | Jessore | −11·2 | Bankura | 39·9 | Midnapur | 26·9 |
| Pabna | −34·9 | Hooghly | −11·1 | Midnapore | 35·9 | Malda | 23·5 |
| Rangpur | −33·7 | Malda | −10·5 | Dinajpur | 35·8 | Bogra | 16·6 |
| Dinajpur | −31·1 | Rajshahi | −9·3 | Khulna | 32·7 | Jessore | 15·0 |
| Jessore | −30·3 | Dinajpur | −9·2 | 24-Parganas | 32·4 | Dinajpur | 13·0 |
| Bakarganj | −11·0 | Jalpaiguri | −6·2 | Pabna | 30·4 | Pabna | 14·2 |
| Khulna | −10·7 | Faridpur | −5·2 | Jalpaiguri | 29·7 | Darjeeling | 9·0 |
| Chittagong | −7·2 | Rangpur | 5·0 | Bogra | 29·3 | Rangpur | 7·5 |
| Faridpur | −5·7 | Howrah | −4·7 | Rajshahi | 29·2 | 24-Parganas | 3·7 |
| Malda | −2·7 | Darjeeling | −4·0 | Rangpur | 22·6 | | |
| Howrah | +6·2 | Bogra | −3·4 | Faridpur | 21·9 | | |
| Bogra | +13·5 | Khulna | −3·2 | Darjeeling | 21·5 | | |
| 24-Parganas | +15·0 | Mymensingh | −3·2 | Howrah | 21·9 | | |
| Dacca | +16·0 | Chittagong | −3·2 | Chittagong | 13·5 | | |
| Noakhali | +24·9 | 24-Parganas | −2·2 | Bakarganj | 12·5 | | |
| Tippera | +39·4 | Bakarganj | −2·6 | Dacca | 11·9 | | |
| Mymensingh | +55·2 | Dacca | −·5 | Noakhali | 8·0 | | |
| Jalpaiguri | +74·8 | Tippera | −0·6 | Mymensingh | 9·1 | | |
| Darjeeling | +146·2 | Noakhali | +2·9 | Tippera | 5·9 | | |

## APPENDIX III.

### Relationship between obstructed Rivers and Malaria in Lower Bengal.

In Lower Bengal, it has long been observed that a deterioration of the public health, more especially from an increase of malaria, almost always occurs in association with the decay of the river systems of the delta. It is often stated that the blocking of river channels is the immediate cause of this ill-health and Government is continually being asked to arrange for the removal of obstructions from the beds of *khals* and rivers in order to diminish sickness and reduce mortality.

2. An extraordinary amount of misconception exists regarding the epidemiology of Bengal malaria. Malaria in the delta tracts, contrary to what has long been taught and is still generally believed, is rarely associated with a great excess of surface water, even when this excess produces actual water-logging of the land and damage to crops.* On the other hand, an intensification of malaria results wherever the drying-up of the delta tracts is carried beyond a certain point. This is particularly noticeable in the case of Burdwan, Hooghly, Nadia and Jessore. The Nadia Fever Commission of 1881 remarked in their report:—

"In fact as Dr. Sutherland observed in 1868, the district is becoming more and more arid, tanks and other reservoirs of water dry up even before the hot season, tanks full to overflowing in the rains rapidly dry up—facts which prove that there has been no increase or excess of moisture in the soil. The very jungle, contrary to the assertions of some natives we met, as Dr Lidderdale points out, is of a kind which prefers a dry to a damp habitat."

3. More recently Babu Bhola Nath Banarji, Executive Engineer in charge of the Special Drainage Division, who has been investigating conditions in Jessore, states in his report of September 1912:—

"If we draw a line from Pultia on the Ichamati to Jhikergacha on the Kabadak, the country lying to the north of this line may be generally taken as suffering from scarcity of good drinking water . . . This is due to the silting of this part of the country by action of deltaic rivers; smaller *bils* do not get any flushing from the rivers . . . . . There are no big sized tanks in most of the villages, and people have to travel a long distance to the nearest river or *bil* for their supply of drinking water. It is reported that tanks in those parts do not hold water, but dry up with the subsidence of the rivers, and are consequently too expensive to be excavated below the subsoil water level. It will not be out of place, if we note the fact that the tracts away from the river and also places which complain of scarcity of water and where *bils* and pits dry up much earlier, are not free from malaria as it ought to be, if dampness alone was the cause of malaria. Most of Jhenida subdivision and parts of the Magura subdivision, where people suffer from want of water and which are away from the big rivers and high lands constitute the most malarious parts of the district."

*This is the exact opposite of what takes place in naturally higher and drier areas, such as the Punjab and Upper Burma

4. The increase of malaria which has gone on side by side with the partial drying-up of certain of the delta tracts of Bengal is in accord with observations in other parts of the world, for it is well-known that large swamps usually remain quite healthy while they are abundantly supplied with water, whereas they often tend to become malarious during the process of reclamation and may remain intensely unhealthy as long as they are only partially dried. The explanation of this is that large water surfaces are rarely a source of anopheles mosquitoes, whereas the grassy or weed-grown edge of a ditch, stream or pool, may often be found to harbour enormous numbers of their larvæ. And the partial draining or drying up of a swamp greatly increases the *ratio* of this dangerous "edge" and may lead to an enormous increase in the output of anopheles mosquitoes. When this fact is grasped, the great increase of malaria that has gone on *pari passu* with the decay of rivers and the drying-up of delta tracts in Bengal may be readily understood.

5. The Presidency Division, which includes the western half of the Gangetic delta, is now much more malarious than when its network of river channels was active. Formerly, it was kept free of malaria by the same agency which maintained the activity of these rivers, namely *the flooding of almost the whole surface of the country during the rainy season with spill water from the rivers.* This flooding of the country temporarily levelled up the surface, abolishing for the time the greater part of the dangerous "edge" of the myriads of *dobas*, ditches and pools, which would otherwise have supplied enormous numbers of anopheles mosquitoes. And although mosquitoes undoubtedly increased when the floods began to fall, the season was then so far advanced that no great spread of malaria could occur. This was probably owing to the fact that anopheles mosquitoes do not become infected with malaria when the temperature has fallen below a certain minimum, neither do they survive sufficiently long to gain infection from malarious patients and become capable of transmitting it again if the atmospheric humidity is low. The flooding of the country with spill water from the rivers, besides preventing malaria, had the effect of flushing the *bils* and it also kept the water-courses open. This was owing to the fact that the enormous volume of comparatively clear water, which had to be discharged from the land surface at the end of each flood season effectually scoured out every channel. Hence the increase of malaria in the delta tracts of Bengal, the silting up of the rivers and *khals* and the obstructed condition of the drainage to which the increase of malaria has been commonly ascribed, are all due to a common cause, namely, *the shutting-out-spill water from the surface of the delta.*

6. The following passage extracted from an unpublished report explains the mechanism of the process of the river decay in the delta—:

"*The description of an active delta branch river.*—If we examine the head of an active branch river or delta effluent, we may observe that the off-take from the main river is roughly triangular or funnel-shaped, that it gradually narrows to a sort of neck where it cuts through the relatively high banks of the main river, and that after passing through this neck the channel usually widens out a little as it enters the lower country beyond. Suppose we take a boat and sail down one of these effluents during the flood season. We shall first of all observe that its banks are raised slightly above the level of the surrounding

country so that the land slopes away from the river. And if the level of the river is high, we may note that water is spilling over wherever the banks happen to be a little lower than usual and is rushing away inland. At the height of the flood season we shall find that, with the exception of the narrow strip of higher land on either side of the river, which is usually densely crowded with villages, the country appears to be almost wholly submerged. But the wide expanses of water, which extend in some directions as far as the eye can reach, are broken here and there by distant lines of trees and dense masses of vegetation marking the presence of ridges of higher land, which bound the channel of some other stream. As we pass downwards, we shall come after a time to the mouth of a small creek or *khal* into which water from the river is flowing. Entering this *khal*, we shall find a narrow winding channel passing possibly for several miles inland. At first its banks are fairly high and like those of our river and lined with villages; but if our boat goes forward, sooner or later, we shall pass out into one of the wide expanses of water that we have noted from the banks of the river. On returning to the river and continuing to travel downstream, we pass the mouths of a large number of the *khals* which serve to connect it with lowlands in the interior. These inland depressions form a series of lateral spill basins on either side of the river, and whenever its flood-level is higher than that in the lateral basins, water continues to flow from it through the *khals* into them. If we examine the same river, when the flood season is over and the water is falling, we shall find great changes occurring. In the first place, the current entering the head is sluggish and the wide triangular off-take is rapidly silting up, with the result that a sort of bar is forming across the mouth and probably a large sandbank is showing well above the water in the centre. When we reach the neck of the effluents, we shall find that a decreasing amount of water is entering from the main river, but where the channel narrows there is probably as yet a fair current. Passing down-stream, we shall find that the banks are now well above the river-level and no water is spilling over them; moreover, the shorter and shallower of the *khals* are probably already dry, although the deeper ones still contain water. *But whereas we noticed during the flood that water from the river was passing into these khals and flowing away inland we now find their current reversed with water from the interior of the country pouring through them into the river channel.* And on passing up a *khal*, we find also that the open country beyond, instead of being submerged as at our former visit, has now become a huge expanse of rice-fields with the crops nearly ready for cutting. The *khal* winds through those rice-fields and finally opens into a *bil* or permanently-flooded area of lowland in the centre. *Bils* which are the lowest parts of the spill basins on either side of the river form the drainage sumps of the country, and the *khals* which lead from them are the discharge channels through which the immense volume of water contained by the spill basins during the flood season eventually passes into the river after having deposited its silt and fertilized the land.

7. "*The mechanism of silting and scour.*—Broadly speaking, a stream of water, such as a delta branch river which flows through a channel composed of sand and silt, may be said to be in a state of silt-saturation. That is, it always tends to carry the maximum amount of silt in suspension that its velocity will allow; and if the velocity of a silt-laden delta effluent were to remain constant it would neither scour nor deposit silt. Hence the silt-laden water, which has entered a branch delta channel from the main river, can only take up more solid matter in suspension if its velocity increases, and on the other hand, it must deposit some of its burden of silt wherever its velocity diminishes. The velocity of a stream of water is largely governed by its volume, its depth and the slope of its surface. And in the case of delta rivers, which experience alternating periods of flood and low water, these factors are constantly varying so that the velocity of the stream is subject to very frequent changes. As a consequence of this, most delta channels (especially those above tidal influence) tend to silt up at certain times of the

year. During the flood season, active delta effluents take off from the main river much larger volumes of water than can be accommodated in their channels; and this surplus water spills over their banks or finds its way into their lateral spill basins by backing up through the *khals*. Thus it comes about that an immense volume of water collects upon the surface of the low-lying country adjacent to an active delta river and is held up there as long as the stream is in flood. And at the end of the flood season as the water-level in the stream is falling, this huge volume of spill water escapes, producing a tremendous scour in every *khal* or discharge channel through which it passes, flushing them out in a very effective manner. This scouring action extends to the river-bed also, and thus effectually counteracts the natural tendency for it to become silted up at the end of the flood season.

8. *The system of a delta effluent.*—A delta effluent possesses a very complex system, consisting of (A) the head or off-take from the main river, (B) the central channel, (C) the numerous *khals* or small branches leading off from the central channel, one season acting as distributaries and at another as feeders, and (D) the lateral spill basins on each side of the central channel of the effluent, with their *bils* or drainage sumps, which are connected with the river system by means of the *khals*. Under natural conditions, a river system of this kind performs a double function: during low water the *bils*, *khals* and the central channel serve the purposes of drainage, carrying off water from the depressed land surfaces of the lateral river basins: but in the flood season the water-courses cease to be drains, and entirely reverse their action, taking on at this time the character of irrigation channels. It is to this system of natural irrigation that active deltas owe their fertility. But this fact has attracted little attention in Bengal, so that the importance of maintaining free river spill from the point of view of agriculture has been almost entirely overlooked. Moreover, the other important function of the river spill in the delta to provide for the natural scouring-out of the water channels has almost escaped notice with the result that irretrievable damage has been done to the rivers in many parts of the delta owing to the restriction of free river spill as a direct consequence of the construction of thousands of miles of embankments. These embankments have been designed either for the controlling of the rivers or for the purpose of railways and roads. But whatever their object, their effect has been the same, namely, in the first place, preventing the flood irrigation which formerly enriched the land and kept it free from malaria and in the second place, disorganizing the natural system of flushing or scour which is so essential to delta channels if they are to remain open. As a direct result of these embankments, the soil of many districts has become impoverished, harvests have diminished and malaria has increased; moreover, silt and sand have accumulated in the beds of many of the rivers to such an extent that they have ceased to be active streams.

9. *The importance of river spill.*—The importance of free river spill in keeping open the channels of the delta is, perhaps, more easily grasped if a few points are illustrated by figures. Let us take, the case of an active delta effluent with a total course, allowing for curves of about 150 miles. A stream of this length will traverse in a direct line about 100 miles of country and in its active

state may possibly feed 1,000 square miles of lateral river basins. At flood season, it will take off from its parent stream a far greater volume of water than that required to completely fill its own channel. This excess water spills over its banks and probably submerges a great part of the 1,000 square miles of lowland or spill basin adjoining it. If, at the height of the flood, the mean depth of water upon the 1,000 square miles of land surface is three feet, over 83,000,000,000 cubic feet of water will be held up alongside the river, ready to be discharged from that channel as soon as the flood-level permits. At the height of the flood, the spill water on the land surface becomes nearly stationary and owing to its loss of velocity is forced to deposit almost the whole of the solid matter it originally carried. As the level of the river falls, this enormous volume of silt-free water begins to move once more and passes gradually from the surface of the country into the river channels. And as soonas it is in motion, it begins to take up solid matter into suspension and scours out the channels through which it passes. If the flood water on the 1,000 square miles of spill area runs off at the rate of an inch in the 24 hours it will form a stream larger than the Thames at Teddington with a volume of 27,000 cubic feet a second; and if, in its passage through the *khals* and the river channel, this water attains a mean velocity sufficient to enable it to lift and carry away one volume of silt in 400 (the water of the Ganges and Hooghly during flood often carries 250 parts of silt per 100,000), it will have removed by the time it has entered the sea over 200,000,000 cubic feet of solid matter from the beds of the watercourses along which it has flowed. Roughly speaking, this would represent a deposit a foot deep and 100 feet wide in about 100 miles of channel. This is the kind of scouring-out process which goes on during the time of a falling flood throughout the whole length of an active effluent channel below the off-take; and it is entirely owing to this process that the upper reaches of branch channels in the delta are kept open and active

10. *Silting at the head of an effluent.*—The off-take of a delta branch river, as we have already seen, is wide at the mouth and contracted at the neck. This contraction has a double effect: during a falling flood in the main river it serves as a check to the velocity of the entering water with the result that silt is deposited in the wide triangular mouth: and with a rising flood in the main river an increasing amount of water is poured into the off-take with the pressure of the rising flood behind it, producing tremendous scour at the contracted neck so that much of the silt and sand deposited in the off-take during low river is washed away. Therefore, the tendency of a delta effluent to silt up at its head during a falling flood is largely counteracted by this tendency to scour with a rising flood; thus as long as every other part of its system is working efficiently, the vitality of the stream is restored at every flood season. The silting at the off-take when the main river is falling seems to be a protective process which automatically shuts off the supply of silt-laden water at a time when the decreasing velocity of the current would tend to cause a deposition of silt in the lower channel. And just at the time when this silting of the off-take is taking place the lower channel is being thoroughly scoured out by the run-off from its lateral spill basins. Hence a silted-up off-take and deeply-scoured lower channel would appear to be the natural condition of a healthy branch delta river at the end of the flood season.

11. *Silting-up of the khals.*—In the case of *khals* leading from the *bils*, an alternate process of silting and scouring also occurs. But in this case the process is the exact opposite of that which occurs at the off-take of a branch river, for silting takes place with a rising flood and scour during a falling flood. We have already seen that *bils* are the lowest portion of lateral river basins which form the spill reservoirs of the rivers in their vicinity. *Bils* are usually possessed of both afferent and efferent *khals*. The former are merely the drainage channels which serve to carry the water from the periphery of the basin to the *bil* or drainage sump, whereas the latter are the channels through which the water collected in the lateral spill basins is finally discharged into the river during a falling flood. Spill water enters river basins either by free flow over the banks of the rivers or through small *khals* which take off from the river. During high flood in the river also water not only pours over the banks into the basins but *backs up through the khals or discharge channels until the level in both basins and river is the same, and at this time silt, often in large amount, is deposited in the khals*. But when the water-level of the river falls, the rush of clear water from the spill basins clears out these channels most effectually as the following example from the Dacca district will show. In 1877, there was a very low flood in the Brahmaputtra, and the *khals* in the Manikganj subdivision became partly silted up as a result of it. But in 1879, there was a high flood and it is recorded that—

"The increased volume of water which left the surface of the thanas during October and November 1879 had the effect, as stated by the District Engineers, of deepening some of these *khals* by as much as 2½ feet."

12. *The vitality of a delta effluent depends upon the integrity of its spill basins.*—Although it is commonly believed that the decay of a delta effluent is primarily due either to the blocking of its off-take or the silting-up of its channel, changes of this sort are not the real cause of the trouble. An effluent system, as we have already seen, consists of a head or off-take from the main river a central channel, and a net-work of *khals* together with a series of lateral basins into which the river spills over when it is in flood. And it is these spill basins that form the most vital, and at the same time the most vulnerable, part of the whole system. For while they continue to receive an adequate supply of spill-water at every flood season, the vitality of the whole effluent system is maintained, whereas deterioration of the central channel, the *khals*, and the off-take through the permanent accumulation of silt is bound to occur whenever the spill area of a river is restricted, either by natural changes or as a result of artificial interference. Mr. Addams Williams, in a recent series of lectures, has graphically described the silting that has been going on in a certain of the tidal channels in the lower parts of the delta, pointing out that this condition occurs wherever tidal spill is restricted. And exactly the same principle applies in the case of the fresh-water channels of the upper delta, the only difference being that in this case we are dealing with a spill of fresh-water during a flood season, in place of a spill of salt or brackish water at every high tide. Once the vital importance of this process of "flush alternating with flood" has been clearly grasped, the necessity for maintaining the integrity of the spill area of delta channels can readily be understood. For it follows

that when the integrity of the spill basins connected with the effluent channels of the delta is destroyed or if from any cause the volume of the flood water passing into these basins is greatly reduced, water-courses are sooner or later bound to be obstructed by silt and sand which gradually accumulates in their beds.

13. *The decay of a branch river in the delta.*—From what has been stated above, it should be obvious that, in the absence of this natural system of flushing, effluent channels can never be self-cleansing, but must eventually become more or less completely blocked. To make this point clear, let us take the case of a hypothetical delta effluent that no longer spills over the country. Suppose this stream to possess a current whose mean velocity during flood exactly equals the velocity at which silt-laden water from the main rivers enters it. In this case the net amount of solid matter carried down to the sea by the effluent during the flood season cannot exceed the amount brought into its channel from the main river, and the scour that occurs in the deep and narrow parts of its channel will be exactly balanced by the silt deposited in the wide and shallow reaches. But when the volume of the stream decreases after the flood season, its velocity will, of course, diminish and a certain amount of silt will then be deposited in its bed. And if year after year this process is continued nothing can prevent the channel from eventually becoming almost completely blocked up In actual practice, other factors, such as rainfall, etc., have, of course, to be taken into account But broadly speaking, a process resembling that just described is now going on in many of the river channels in the older parts of the Gangetic delta. For, on examining one of these dying rivers, we find, in the first place, that, at end of every flood season, silt begins to accumulate in its bed as the velocity of the current diminishes, and remains there because the run-off of relatively clear water from the lateral river basins is so small owing to the shutting-out of river spill that it cannot provide an efficient scour. In the second place, we may see that the silt deposited in the *khals* when water from the river is packed up in them at a time of flood, remains in their channels owing to the fact that the *bils* with which they are connected only provide a very little water for flushing out their beds when the water-level of the river falls. From what has been stated, it should be clear that the accumulation of silt in the channels of a delta river system is directly due to the greatly-diminished supply of water received by the adjacent land surface; and this silting-up must not be regarded as the primary cause of the decay of the river channel, but should rather be looked upon as a symptom of the disorganization of the system of lateral spill basins which has led to their being deprived of an adequate supply of water during the flood season. *A change of this sort may come about naturally, as for example, when a delta river has raised its banks to such an extent that water can no longer spill over them even at high flood. But it appears more often to be the result of artificial interference, such as that occasioned by river embankments or to the shutting-out of free river spill owing to the construction of roads and railways.* The causes of river decay are, therefore, to be sought, not in the affected channels themselves, but upon the adjacent land surface of the delta. It follows that attempts at merely clearing the bed

of a damaged waterway can rarely effect any permanent improvement. Moreover, work of this kind may in some cases actually accelerate deterioration, as, for example. when the off-take of a stream, already shut off from its spill basins, is dredged during low flood so as to allow a larger volume of silt-laden water to enter it from the main river. A case of this sort occurred recently near Faridpur station where two or three years ago the dredging of the head of a small river, whose spill had been somewhat limited by the raising of a road that ran alongside it, was followed by the tremendous silting-up of the off-take and channel. It is possible also that the present deplorable condition of the upper reaches of the Bhagirathi is partly a result of the attempts that have been made for years past to keep the head of that river open during the season of low water, whilst at the same time free river spill during flood has been almost entirely prevented by means of embankments."

14. In the past, the question of river decay in relation to the public health has been considered only from the point of view of drainage, for medical men and egineers, as well as the lay public, have been obsessed by the idea, *firstly*, that "obstructed drainage" is the cause of Bengal malaria; *secondly*, that the rivers in the delta are mere drainage channels; *thirdly*, that the collection of silt and other obstacles in the beds of these channels is the cause of this obstructed drainage; and, *fourthly*, that this condition can be remedied by the removal of obstructions from riverbeds or by special drainage schemes. It is these views which led to the passing of the various Bengal Drainage Acts; the same ideas inspired the Special Drainage Committee of 1906; and similar notions underlie every recent proposal for the clearing of dead riverbeds and carrying out of large drainage projects with the idea of improving the public health of rural areas. But none of the remedies yet proposed can possibly effect the purpose intended. For the evils which require relief are due neither to water-logging nor to deficient drainage. On the contrary, they are the results of a greatly diminished supply of surface water. As regards the clearing out of dead river-beds, a measure which has often been suggested as a remedy for the great deterioration of the public health that has taken place in many parts of the delta, it may be remarked that, in the first place, this measure will not increase the total supply of water nor prevent the growth of weeds, and although it might lead in some cases to more water being temporarily diverted down one or other moribund waterway, in the conditions generally existing, this result can only be obtained at the expense of other channels, and may, therefore, do as much harm as good.

15. Among the arguments put forward in support of attempts to improve dead rivers by the clearing-away of fishing weirs, and *kumars* and by re-opening, if possible, the portions of their beds that have already been brought under cultivation, the question of depopulation has been introduced; and, in a recent case, it has been suggested that "the removal of obstructions alone would do immense good to the drainage and by keeping the river alive, the depopulated villages on its bank may again revive" It may be remarked that the occurrence of depopulation is continually being urged as a reason for carrying out projects of this nature. This being so, it will be well to briefly discuss this phenomenon of depopulation, which, in the

popular mind, is supposed to be a direct result of disease. But this view, it may be remarked, only explains *how* a reduction of population is brought about, and provides no answer to the more fundamental question of *why* a population declines. Yet it is the latter problem that must be solved if we are to check the evil. And in this connexion, the following passage from Mr. Udney Yule's *Theory of Statistics* is illuminating :—

"If the population of a district is increasing at a rate above the average, this is *prima facie* evidence that its industries are prospering : if the population is decreasing or not increasing as fast as the average, this strongly suggests that the industries are suffering from a temporary lack of prosperity or permanent decay."

16. The population of Nadia and Jessore districts, which have long showed a tendency to decline, are dependent almost entirely upon agriculture ; and the condition of that industry may be gauged from the fact that during the decade 1901-11 the outturn of crops, per acre cultivated, has fallen very short of the normal in both Jessore and Nadia, the deficiency being over 30 per cent in the former district and nearly 40 per cent. in the latter. The cause of this deterioration may be inferred from the following quotations :—

"*Diminished fertility of the soil in Nadia.*—There is a consensus of opinion among Europeans and natives that, except in the lower lands used for the rice crop reaped in the cold weather, there is a distinct decrease in fertility of the soil of Nadia Considering that no land except that used for sugarcane and tobacco is ever manured, and that the Ganges floods which are so fertilizing are shut out by the embankments of the rivers, it is not to be wondered at that gradually the soil should b come partially exhausted." (*Report of the Nadia Fever Commission of 1881.*)

"There is no doubt that the soil is getting less and less fertile. The average yield of crops is low as will be seen from the fact that the average yield of winter rice is 805 lbs. per acre and of autumn rice 835 lbs, while in Jessore it is 1,145 and 870, and in the 24-Parganas it is 843 and 1,014, respectively. Another noticeable feature is that it is becoming necessary to allow the land to lie fallow for longer periods between croppings. During the five years from 1904-05 to 1908-09 only about 40 per cent. of the total cultivable area was actually cropped." (*Bengal Census Report of 1911.*)

"In Nadia the soil is deteriorating on account of the gradual silting-up of the rivers." (*Report of the Director of Agriculture, 1910-11.*)

"It is reported that cultivation has suffered from the deterioration of the rivers, which year by year used to deposit a layer of silt on their banks and in the *bils* during the flood time . . . This natural form of fertilization has ceased. . . . The area under *aman* rice is contracting, owing to deficient floods." (*Jessore District Gazetteer.*)

"Owing to the rivers having silted up at their head . . . the periodical inundations, which used to occur when they were in flood, have ceased. In the Jhenida sub-division there have been no floods for the last 15 years, and the country is the poorer for it, while in the Magura sub-division the floods are now comparatively slight and the land is not fertilized to the same extent as formerly." (*Jessore District Gazetteer.*)

17. The facts recorded in the passages quoted afford an adequate explanation of the decrease of population that is going on in Jessore and Nadia. Any increase of population would be impossible under the circumstances mentioned. Depopulation, therefore, is occurring in these districts, because the land can no longer support a population as dense as it once could, owing to the decrease that has taken

place in agricultural production. To put it briefly, the population must decline, because the available food-supply has been diminished.

18. In Lower Bengal, river decay, agricultural deterioration, increased prevalence of malaria and depopulation are all due to one common cause; namely, the shutting-out from the land surface of the delta of the flood water which, while it remained on the surface of the country, fertilized the soil, kept down the number of anopheles mosquitoes, and thus prevented malaria, and when it passed back into the river channels effectually scoured out their beds and so preserved their vitality. And the evils that have followed the stopping of these annual floods cannot be remedied by schemes for the tidying-up of dead river channels or the further drying-up of a country which is already suffering acutely from a greatly-diminished supply of surface water. From every point of view, therefore, projects of this sort must be condemned. They are based upon an entire misconception, *firstly*, of the character of delta channels; *secondly*, of the origin of their decay; *thirdly*, of causes underlying the increase of malaria in the delta tracts; and, *fourthly*, of the factors responsible for depopulation. Nearly every scheme for the improvement of the sanitation of rural areas by drainage projects or the betterment of rivers that has been put forward in recent years is open to these fundamental objections. Many of these proposals aim at removing from the land surface of the delta as much water as possible, usually by some system of drainage. But measures of this sort, if successful in diminishing the surface water during the rainy season, will almost certainly intensify malaria and increase depopulation—the very evils that they are intended to remedy. On the other hand, any scheme which will provide for *increasing* the supply of surface water during the monsoon and for so controlling it that neither too much is collected on the land for agricultural purposes nor too little allowed to remain there for health, ought to receive every consideration, in view of the fact that we now possess definite evidence to show that in Lower Bengal the greater the amount of flooding of the land surface during the rainy season, the less malaria will there be.

## APPENDIX IV.

### Drainage of *Bils* as a Public Health Measure.

For many years, it has been supposed that the mitigation of malaria in the rural tracts of Bengal can best be accomplished by drainage. And with this view, proposal for the drainage of large swamps or *bils* are frequently put forward as sanitary measures. But an extraordinary amount of misconception exists regarding the epidemiology of Bengal malaria, because recent investigation has shown that contrary to what has long been taught and is still generally believed, malaria in the delta tracts is not associated with a great excess of surface water, even when that excess produces actual water-logging of the land and damage to the crops.* On the other hand, an intensification of the disease occurs wherever the partial drying up of the country is carried beyond a certain point, this condition being particularly noticeable in the districts of Burdwan, Hooghly, Nadia, Jessore, Murshidabad, and in a few parts of the Dacca and Rajshahi Divisions.

2. The Nadia Fever Commission of 1881 remarked in their report—

"In fact, as Dr. Sutherland observed in 1868, the district is becoming more and more arid, tanks and other reservoirs of water dry up even before the hot season, tanks full to overflowing in the rains rapidly dry up—facts which prove that there has been no increase or excess of moisture in the soil. The very jungle, contrary to the assertions of some natives we met, as Dr. Lidderdale points out, is of a kind which prefers a dry to a damp habitat."

And more recently Babu Bholanath Banarji, Executive Engineer, in charge of the Special Drainage Division, who has been investigating conditions in Jessore, states in his report of September 1912—.

"If we draw a line from Pultia on the Ichamati to Jhikergacha on the Kabadak, the country lying to the north of this line may be generally taken as suffering from scarcity of good drinking water . . . . This is due to the silting of this part of the country by action of deltaic rivers . . . . . There are no big sized tanks in most of the villages, and people have to travel a long distance to the nearest river or *bil* for their supply of drinking water. It is reported that tanks in those parts do not hold water, but dry up with the subsidence of the rivers, and are consequently too expensive to be excavated below the subsoil water level It will not be out of place, if we note the fact that the tracts away from the river and also places which complain of scarcity of water and where *bils* and pits dry up much earlier, are not free from malaria, as it ought to be, if dampness alone was the cause of malaria. Most of the Jhenida subdivision and parts of the Magura subdivision, where people suffer from want of water and which are away from the big rivers and high lands, constitute the most malarious parts of the district."

3. The view expressed in the above passage confirms the statement made by Babu Umesh Chandra Ghosh, B.L. (one time the Chairman of the Jessore Municipality, and Vice-Chairman of the District Board), in a pamphlet published in 1905, to the effect that—

"It may be pointed out that the unhealthiness of this district (Jessore) is not due to the humidity of the soil caused by the presence of the *bils*, but to the diseased condition of the rivers. Some of the rivers are half dead, while others are slowly dying. The districts of Bakarganj and Faridpur, which abound

* This is the exact opposite of what takes place in naturally higher areas such as the Punjab and Upper Burma.

with *bils* of various sizes, are not unhealthy. Pargana Telihati, which consists of more than 300 villages, is mostly covered with *bils*. If one looks at a map of the pargana he will see nothing but a vast sheet of water, dotted with elevated earthen mounds here and there, which are utilized for the purposes of human habitation. The people, though living in these *bil*-clogged villages, are robust and healthy. There can be no doubt than that the existence of the *bils* is not the cause of the malaria which prevails in this district.

4. The fact that in Jessore malaria is most severe on land which is relatively high and in areas which are suffering from a lack of water rather than an excess, is in accord with many earlier observations in other parts of Bengal. For example, Dr. Jackson, when reporting in 1872 on the outbreak of epidemic fever in the eastern portion of Burdwan district, states that—

"It was more fatal in the higher and better drained than in the low lands."

Dr. Wise, writing in the same year about the occurrence of severe malaria in the Manikganj subdivision of the Dacca district, remarks :—

"The causes which have rendered this subdivision the most unhealthy in the whole district are not, I think, difficult to indicate. It is the most northern, the most elevated, and the driest in the district The rainfall is much less than at Dacca."

The Sanitary Commissioner, reporting in 1877 on a servere outbreak of malaria in the Keshpur and Narangarh circles of Midnapur, observes that—

"These circles are well raised and comparatively dry, suffering as a rule rather from drought than excess of the moisture."

The Civil Surgeon of Faridpur, commenting in 1884 on the prevalence of malaria in the thanas in the north-west of that district, adds that they—

"Are situated high above the level of the floods."

And a year later, the Sanitary Commissioner quotes the Deputy Magistrate of Chuadanga subdivision of the Nadia district as remarking that—

"The prevalence of fever in his subdivision appeared to be due to deficient water-supply."

5. The instances cited above suffice to show that, unlike other parts of India, possessed of widely different physical configuration and climate, the delta tracts of Bengal almost invariably show an increased prevalence of malarial infection whenever the amount of water, which ordinarily collects on the land surface during the wet season, is seriously diminished ; whereas villages in the midst of large swamps or situated in badly drained low-lying areas liable to flooding during the rainy season often possess populations of superior physique, vitality and fecundity, and at the same time enjoy a comparative immunity from malaria. This fact has

frequently attracted attention The Lieutenant-Governor of Bengal, in a note upon the Burdwan fever published in 1873, remarked—

"I am very much struck, in comparing the population returns with the map, to observe that the highest population almost exactly corresponds with the tract marked by Colonel Haig in the deepest colours as most in want of drainage and improvement and with a similar tract in Midnapur, which has similarly suffered from flood, and the difficulty of carrying off the water, as I myself witnessed a few months ago. Colonel Haig gives a vivid, and, I may say, horrible description of the tract, as one in which there is absolutely no healthy flow of water whatever, and no escape—a hollow in which the water stagnates, and a mass of decaying vegetation festers in it ; where noxious fumes exhale in the hot weather, while the damp of the raw cold weather, and extremes of temperature then prevailing render it still more unwholesome. Yet, in the reeking swamps the human race seems to have multiplied to a greater extent than any where in India—perhaps in the world. It seems, as if it may be almost said, that we cannot have too much water in this country, and that, in such conditions in this climate, all sanitary science notwithstanding, the human race multiply till it is wasted by great calamities. As it is, Colonel Haig truly observes that up to this time there has been much less fever in these reeking swamps than in the higher parts of Burdwan and Hooghly where there is a sensible natural drainage."

In 1884 also, Dr. Ghosh, Deputy Sanitary Commissioner, when reporting on the health conditions of villages in the Bistupur thana of the Diamond Harbour subdivision of the 24-Parganas, observed that—

"These villages are all situated on the *bils* (cultivated, and known as the *bads*) in connection with the Kaurapukur *nala*, the huts are peeping out of a vast sheet of paddy fields, and almost every house has to be reached by means of a dug-out. Paddy cultivation, fishing and duck farming are their principal occupations. The people seem to be in perfect health, children fat and healthy, women strong and hard-working, very different from what is seen in a Bengal village. This proves what I have always maintained, that moisture *par se* is not the origin of malaria. There is too large a quantity of water here for it to be injurious . . . . . Go to the south of the Khulna district and parts of Barisal, cultivated very largely with paddy, and there one cannot help being struck with the fine robust constitution of the people."

6. This extraordinary immunity from fever often enjoyed by *bil* villages greatly impressed the medical men and other officers who investigated the Burdwan epidemic. Colonel Haig, R. E., reported that—

"No connexion has yet been traced between the intensity of the fever and proximity to stagnant marshes . . . On the contrary, there are numerous facts which are absolutely irreconcilable with such a supposition. Some of the villages on the borders of the Dankuni *jolas* have been distinguished by comparative immunity from the fever, while it has raged in others which are quite free from swamps. The Collector reports that Chanditola and the neighbouring village at the south-west corner of these swamps have generally been considered "exceptionally healthy."

And Mr. Grant, Magistrate of Howrah, remarked in the same connexion—

"I have only to say that everyone who has studied the subject must have been struck with the fact that the fever constantly (indeed very generally) avoids these horrible swamps."

Babu Ramesh Chandra Mukharji reported also that—

"The villages situated in the approaches to, and in the very hearts of, the great marshes—the Rajpur jhil, the Kaiderah *jola*, the Bura *jola* and the Panchla *jola*—have enjoyed comparative immunity from fever."

And Dr. Sutherland observes that—

"The village of Jenkari is on the edge of a vast tract of swampy country and yet is healthy. Not a few examples of the same kind are to be found near."

In other portions of the Burdwan Division, the experience of Drs. French and Jackson afforded further confirmation of the view that villages in very swampy situations as a rule escaped a serious amount of fever. The former officer remarked that—

"Villages in the vicinity of large jhils suffered very little, if at all, from the fever."

And the latter stated very definitely that—

"Villages on *bils* have not been more unhealthy than others, but quite the reverse, even when their sites are flooded in the rains."

7. The condition of things described above is by no means exceptional. Lieutenant Colonel (now Sir Leonard) Rogers, I.M.S., as recently as 1909 called the attention of the Simla Malaria Conference to the fact that—

"In the 24-Parganas, the Sundarban area, which was practically flooded, was the most healthy part of the district."

And Lieutenant-Colonel Fry, I.M.S., in his Second Report on Malaria, points out that villages in the Singur and Chanditola thanas of Serampur subdivision of Hooghly (an area in which the drainage is the described as being "very congested") remain singularly free from malaria. The author of this note also has recently reported on the existence of a similar condition of things in the Howrah district and in the *bil* tracts of Madaripur and Dacca, which all enjoy a remarkable immunity from malaria in spite of numerous swamps and a general excess of surface water. Moreover, there is an exceedingly simple explanation of this apparent anomaly.

8. Ross has shown that the prevalence of malaria in any locality bears a definite relation to the ratio borne by the number of anopheles mosquitoes present to the human population residing there. And he has also pointed out that malaria cannot exist unless the actual number of anopheles mosquitoes per head of the population exceeds a certain minimum. The number of anopheles mosquitoes occurring in any place is governed by the facilities which exist for their breeding, and although insects can only multiply where there is water, the character of the collections of water available for their breeding exerts an important influence upon the actual number produced. Observations have shown, in the first place, that small collections of water are relatively more favourable to the breeding of mosquitoes than large ones; and, in the second place, that it is only the edges as a rule, especially in the case of large collections of water which afford shelter to their larvæ. And, broadly speaking, it may be stated that the number of anopheles present in a

definite area is probably determined by the amount of water "edge" existing there. If the ratio of edge is low, the anopheles will be relatively few, and if it is high, it is certain that they will be exceedingly prevalent; and as the prevalence of anopheles mosquitoes varies with the amount of water edge, so also will the intensity of malaria tend to vary in the same way.

9. A little consideration will show that the amount of water edge in any area is not governed by the extent of water surface present there; for a large collection of water may have very much less of the dangerous edge than that provided by a number of smaller pools, which in the aggregate possess a very much smaller surface. If, for example, we take the case of a circular *bil* about one mile in diameter, we have, roughly speaking, three miles of edge, or in other words three miles of potential breeding places for mosquitoes. If this *bil* were to be drained absolutely dry, the three miles of dangerous edge would of course be abolished, and the *bil* would cease to be a danger from the point of view of malaria. But if we cannot entirely dry the *bil*, drainage may be a very risky measure, if it does not reduce the amount of water edge existing during the rainy season (the only period which we need bother about because it is the only season when malarial infection can be contracted). The attempt at drainage under these circumstances will not diminish malaria, but on the contrary it may lead to an actual increase of the disease. The reclaiming of La Chartereuse swamp near Bordeaux is a classical instance of this. Work was commenced in the summer of 1805 with the result that an appalling epidemic occurred causing 18,000 cases of pernicious malaria and 3,000 deaths. Similar results have been observed in England also. Dr. Paley, reporting to the Privy Council in 1860 on the subject of an epidemic of malaria at Peterborough, remarked—

> "The first effect of the improved drainage of the large ten districts of our neighbourhood, especially those which were formerly constantly covered with water, like Whittlesea Mire, has been rather to increase the prevalence of ague."

The ten districts of England are now comparatively healthy, but, as is well known, they were specially reclaimed for wheat cultivation, and the requisite drying up of the soil was obtained by the use of pumps actuated by windmills, replaced in latter years by steam engines.

10. In the case of the delta tracts of Bengal, the configuration of the land surface, the heavy rainfall it experiences, and the character of the crops cultivated make it impossible to dry up the country during the wet season, and in these circumstances attempts at reducing the amount of water on the land surface are almost certain to be followed by an increased amount of water edge, an increased production of anopheles mosquitoes and an increased prevalence of malaria. This point can be easily made clear by means of the diagrams attached. Eastern Bengal and other areas subject to flooding are kept healthy, owing to the fact that in these areas all the hollows, pits, *dobas* and irregularities of the land surface, the edges of which would harbour mosquito larvæ if they contained a limited amount of water, are merged in the general inundation, levelled up so to speak, and thus rendered almost harmless; whereas in parts of the delta no longer subject to inundation the myriads of potential breeding places of this kind are no longer neutralized by flooding,

and as a result enormous numbers of anopheles mosquitoes are produced during the rainy season and malaria becomes proportionately prevalent and severe.

11. But, although partial drying up of delta areas may be exceedingly dangerous and suggested drainage schemes for the rural tracts of Bengal must only be adopted after the most careful enquiry and examination, there are alternatives which promise excellent results. These alternatives may be described briefly as (1) temporary flooding and (2) irrigation.

In Bengal, the accidental flooding of malarious areas has almost invariably led to a temporary amelioration of malaria. And it may be pointed out that this method of combating the disease was made use of over 2,000 years ago by Empedocles, who is recorded to have freed the city of Selenos of malaria by flooding the swamps which surrounded it with water brought in by means of canals and aqueducts. At a much later period also Lancisi made use of the same methods to reduce the prevalence of malaria in parts of Italy.

12. Besides these examples, we have evidence to show that the introduction of an added supply of water into specially unhealthy areas in Bengal has also led to an improvement in health.

Dr Coats, when Sanitary Commissioner of Bengal, records the fact that—

"The admission of the Damudar water into the Kana Nadi in 1873-74 and 1875 was followed by an immediate and marked amelioration in health"

And Dr. Dutt of Serampur, who visited this area in 1879, stated that—

"The letting in of the Damudar water was a most welcome relief, and that, but for it parts of the country would have been entirely depopulated It has been allowed to flow in 1878 and 1879, and the people say that the epidemic has disappeared since the last two years. These facts leave no doubt that the letting in of the Damudar water in the Kana Nadi and through it into the khals, drains and tanks, etc, in the interior of the subdivision, has led to this improvement"

That this view was not merely imaginary is shown in a further report by Dr. Coats, wherein he remarked—

"At a recent visit, I myself found only two per cent of the people suffering from the effect of former fevers, enlarged spleen and anæmia The pathshalas were full of healthy boys, not one of whom had splenic enlargement, cultivation was going on actively, and people were eager to have increased water supply and drainage."

13. In view of the reference to drainage in the above passage, it may be urged that villagers in Bengal often clamour for drainage and that several large scale drainage schemes that have been already carried out, notably the draining of the Dankuni *jolas*, the Howrah and Rajapur swamps, and the Magrahat Drainage Scheme appear to have been followed by excellent results. But what are the real facts? Colonel Haig, R.E., reporting on the Dankuni Drainage Scheme in 1878, five years after its completion, observed—

"In the first place, then it may be remarked that experience has proved not merely that it is only in so far as irrigation can be combined with drainage that the full benefit of these schemes can be derived, but that for all practical

purposes the improvement is limited to the area for which irrigation is available . . . . Contrary to all expectation, the experience of the five years which have passed since the completion of the works has shown that in years of ordinary rainfall . . the sluices and drains are required much more for letting in water from the Hooghly for irrigation than for draining it off .

Thus in 1873, during 153 . . days from June to October in which there was a rainfall of 34 inches, the sluice-gates were never once opened for drainage, but were opened 15 days for admission of water In 1874, with a rainfall in the same months of 41 48 inches the sluices were not once worked for drainage, but during 13 days for irrigation. In 1875, the rainfall was 34·62 inches, and the sluices worked eight days for drainage and 15 days for irrigation In 1876, with a rainfall of 46 71 inches the sluices were opened for drainage for eight days, and for irrigation for 26 days. In 1877 with 38 inches of rain, the number of days were 4 for drainage and 22 for irrigation The capacity of the sluices is in fact determined, not with reference to the requirements of drainage at all, but to those of irrigation , it must be such as experience shows to be necessary to raise the level of water in the low grounds with the gradual growth of the plants, and this is probably in excess of what is required for drainage, though the point has yet to be determined by a year of excessive rain, which we have not had since the works were finished The average rainfall in Hooghly of the five months referred to is given by the Meteorological Department at 50 72 inches These are very curious facts and show what an immense proportion of the heavy rainfall of Lower Bengal is consumed in the process of vegetation, the rice plant apparently requiring a great part of it, and the rest passing off chiefly by evaporation, for the subsoil drainage appears to be very small It also appears from what has been said that some very important experience has been gained in this our first experiment in drainage on a large scale in India, as it is now found that it is sufficient if the discharging capacity of the drains is not above one-ninth of what was originally thought necessary

The Magistrate of Howrah, also writing of the Howrah and Rajapur Scheme in the Annual Administration Report of 1897-98 remarks—

'All the drainage schemes have proved to be of immense benefit in reclaiming waste swamps and improving the other lands They were originally intended for the drainage of the swamps but they are now advantageously utilized in irrigating the lands, in years of drought and scanty rainfall, with fresh water from the Hooghly river

More recently in 1905, the Commissioner of the Burdwan Division stated of these works—

"These schemes have proved very successful in reclaiming the extensive waste swampy lands west of Howrah and improving other lands The surplus water is drained out by the channels and sluices in years of heavy rainfall , while in years of drought, water from the river is let in for cultivation and drinking purposes The schemes have been of great benefit to the people of the neighbouring tracts, who can reap a good harvest in years of drought, as well as in years of heavy rainfall '

And exactly the same thing may be said of the Magrahat Drainage Scheme, which has also successfully combined the functions of irrigation with that of surface water control

14. All the above schemes, it may be observed, although applied to *bil* areas and spoken of as "drainage schemes," are, strictly speaking, schemes for irrigation. And it is owing to this fact that they have not led to an increase of malaria in their vicinity For although the introduction of irrigation into dry countries like the

Punjab and upper Burma is often followed by an extraordinary increase of epidemic malaria, in swampy ow-lying deltas it has a contrary effect, as is shown by the history of irrigation in the deltas of the Kavari and Godavari in Madras.

In 1809, Tanjore suffered from severe epidemic malaria which followed upon scarcity of water, owing to the decay of the irrigation system of the delta originally organized some 1,600 years ago in connexion with the *Grand Anicut*. Before the trouble was finally remedied, Tanjore had lost 25 per cent of its population; but very shortly after a plentiful supply of water for flush irrigation was secured by the projects of Sir Arthur Cotton, Tanjore became a prosperous and comparatively healthy district once more. And the history of Godaveri is very similar, for that delta district was fast passing into a state of decay, depopulation and bankruptcy when Sir Arthur Cotton designed the irrigation of the delta. And as recently as 1872 and 1873 this area suffered from epidemic malaria. The irrigation system of the Godavari delta was finally completed in 1891, and the Gazetteer of the Godavari district contains following reference to the present health conditions in the district:—

"The fact remains that the delta taluks (unlike irrigated areas in some places in this Presidency, the valley of the Tungabhadra for example) are not greatly subject to malaria, and are, in fact, the part of the district in which it is least prevalent."

15. A consideration of the facts brought forward in the preceding paragraphs leads to the conclusion that in the delta tracts of Bengal it is necessary to approach the question of the drainage of rural areas with the greatest circumspection. This is all the more necessary, because of the frequent demand for the drainage of *bils* on the ground that the carrying out of projects of this kind will not only bring new land under cultivation but greatly reduce prevalence of malaria. As regards the pecuniary advantage likely to accrue to the owners of the land that may be reclaimed by such measures, there is no question, as I showed in a previous note, that it may in some cases be enormous. But I confess that I fail to see in what manner the drainage of many of these swamps can possibly benefit the health of communities in their neighbourhood that may be suffering severely from malaria. In this connexton I would once more call attention to the view, expressed in a previous report upon a scheme for the drainage of the Arool Bil, that this scheme can in no sense be considered a sanitary measure. Formerly the scheme proposed was for the removal of water only. It has been considerably modified however and regulators and sluices provided, so that the depth of water can be controlled. Regulation and control of surface water is more desirable than mere drainage, which, while perhaps benefiting a small area of perennial swamp, does so at the expense of the elevated land in its vicinity. But where drainage schemes can be combined with irrigation much lasting good may be expected.

## APPENDIX V.

### Flooding or Covering by Water as a Method of Anti-malarial Sanitation.

The article on malaria in Hirsch's Handbook of Geographical and Historical Pathology, when discussing the effect of floods upon the prevalence of the disease, remarks upon :—

"The fact that, *when the water is high and the ground completely covered by it*, the endemic or epidemic disappears, fresh cases of the disease appearing only after the water has run off and the surface of the country has been laid bare. Classical examples of this are furnished by the malarious regions periodically inundated on the banks of the Nile, Indus, Euphrates, Ganges, Senegal, Niger, Mississippi and other rivers, where the endemic always begins after the waters have begun to subside. There is another illustration of the fact in those rice-fields in India which are always under water, and, as Annesley remarks, are the least dangerous to health. Experience also in Turkey (Sandwith), in Sardinia (Morris), at several places in the Southern States of the Union (Nott), in England (Royston) and elsewhere, proves that the complete flooding of marshy ground, and the filling up of standing pools, ditches, and the like causes the endemic to disappear as certainly as if they had been dried up."

More recently, Deadrick in his text-book on "The Study of Malaria" (1910) gives the following example of the effect of floods upon malaria :—

"The primary effect of the submerging of land, while the water is high, is to diminish malaria. A remarkable example which illustrates this occurred in Holland in 1748. The Dutch allowed the land, for defensive purposes, to become overflowed. Peace being concluded during the middle of the summer, the inundation was caused to subside, whereupon a serious outbreak of malaria occurred. The epidemic was not successfully combated until the land was again submerged and kept so until the advent of winter. The effect upon malaria of inundations is almost yearly observed in the valleys of the Nile, of the Mississippi, and of other large streams."

Many other authorities also have called attention to very similar facts. For example, Davidson states that :—

"In some marshy countries, a heavy rainfall diminishes the prevalence of fever by covering the marshy ground with a protective sheet of water. Thus in the Netherlands, it has often been remarked that rainy years are healthy years, while hot and dry seasons are feverish."

Schellbe, speaking of conditions affecting malaria prevalence, remarks that :—

"Very heavy rain has a deterrent influence on naturally damp soil . . . At the height of the rainy season . . . in Deli in Sumatra (Martin) and New Guinea (Schellong), the minimum number of cases of illness is notified"

And he explains this by observing that :—

"A thorough soaking of the soil is deleterious to the development of the mosquito"

Craig also records that :—

"In many regions, however, where abundant rains occur, malaria is rare, even though the anophelines are present. This is explained by the fact that in such regions the rains are so heavy and continued that the breeding places of mosquitoes are washed out and ova and larvæ do not have a chance to develop, or that no infected individuals are resident in the locality. In the former instance an unusually heavy rainfall may act as a protection against malaria."

Manson too has observed the same thing and explains it in the following passage :—

"In some places, particularly in those that are low lying, flat, and swampy, fevers of first invasion disappear almost entirely when the country becomes flooded . . . In some places much rain will scour out the mosquito pools, in other places it will just fill them . . . The key to the explanation of the varying relation of malaria to rainfall is to be found in the influence of the latter on the local mosquito pools."

2. The passages quoted above show that it has long been recognized that the flooding of a country may exert a beneficial influence upon malaria. And authorities like the late Professor Angelo Celli and Professor Julius Mannaberg have always regarded flooding or "covering by water" as useful measures for the control of the disease The former author refers in his classical monograph on "Malaria according to the New Researches" to this method of combating malaria in the following words :—

"Covering can, so to speak, also be made with *water*. If a stratum of water be made to cover a malarious site, so long as the water remains at a constant level there will be brought about a relative improvement . . This submersion in certain cases is only relatively beneficial, and its real value will have to be tested in the light of the new theory regarding the origin and propagation of malaria by means of mosquitoes Thus perhaps will be explained what seems to be a paradox, namely, that the suppression of an epidemic of aquatic origin is brought about by the presence of water"

And in Nothnagel's Encyclopædia of Medicine, the latter writer, when discussing the prevention of malaria, remarks that :—

"In swamps, where drainage was impossible, a regular level was aimed at, especially during the summer months, by the regulation of the incoming and outgoing water, and by the building of dams since it was not the surface covered with water but that which was alternately under water and exposed to evaporation, which was dangerous."

Adding that : —

"Exceptionally during severe epidemic radical measures were undertaken, as for instance, the copious flooding of malarial foci. This was first put into practice by Empedocles, later by Lancisi."

Some investigations by Lieutenant-Colonel Hodgson and King, I.M.S., serve to throw a new light upon the rationale of phenomena of the kind referred to and enable us to understand why "*floating or covering by water*" may be a most useful measure of anti-malarial sanitation. The following passage is extracted from

Lieutenant-Colonel Hodgson's note in the Proceedings of the Lucknow Sanitary Conference, 1914 :—

"Taking the mosquito in its larval existence, we found that the optimum temperature for anopheles lay between 68°—78°F. Temperatures above 80°F. became more and more unsuitable, while temperatures of 95° to 104°F. were rapidly fatal. In nature, during the monsoon at Delhi in August, and in Madras in November, we found the surface of pools to vary from 73°F. to 104°F., the difference being due to the following important facts :—

(1) The *coolest* pools were very small pools lying amongst grass.
(2) The edge of a pool in the day time is cooler than the centre.
(3) The surface layer is often 3° or 4° hotter than the water 4 or 5 inches down at midday.
(4) The water lying at the shallow edge, round grass stems, is the coolest part of a pool.
(5) When the average temparature of pools had risen to 90° or even 100°., falling rain both at Delhi and Madras was found to be 73° to 77°F., during the monsoon.
(6) The river at Delhi even after long drought never rose above 87°F. at midday.
(7) Well-water varied from 80°F. to 82°F.
(8) The sea at Madras in the monsoon was 80°F.
(9) Small hoof marks in grass might contain water 90°F. cooler than a large pool 6 inches away, particularly during hot dry weather

"An anopheles mosquito lays her eggs in that type of pool which is coolest at the time. The struggle for existence rapidly increases above 80°F. and temparatures such as 104°F. are fatal to every single larva in less than 18 hours, though this is a temparature at which some pools have been found in nature. In the Terai in October water varied from 65°F. to 78°F. on the two days we examined it, and anopheles were breeding in millions The great destroyer of mosquito larvæ is nature and her principal means is raising the temperature of the water."

3. It will be seen from these observations that small collections of water and those possessing a large ratio of weedy edge are far more dangerous than large water surfaces, because they invariably possess a lower temperature much more suitable for mosquito larvæ than the high temperature to which large collections of water speedily become raised. This fact helps to explain the beneficial effect of flooding upon the prevalence of malaria. When water is admitted in large amount to the surface of a low-lying country, all the small pools are converted into large ones ; on the one hand the ratio of dangerous edge is greatly reduced and on the other hand the temperature of the water is speedily raised with the result that the output of anopheles mosquitoes is restricted. And when this measure can be adopted with advantage from the point of view of agriculture also, as it may in countries where the population is largely dependent upon wet crops, a doubly beneficial result may be expected.

4. In regard to the use of flooding as well as in the case of other antimalarial measures specially directed against mosquitoes, there is another point which requires consideration. This is the fact that, broadly speaking, it is in the rainy season only that measures of this kind are required. Moreover, it is only at this time of the year that they can prove effective. An examination of the monthly curve of admissions from malaria will show that the disease usually begins to show an increase in the month of July or August, reaches its maximum in September or October and speedily declines

in November. If we compare this sickness curve with the curve of mosquito prevalence, we shall find a remarkable correspondence between them. That is to say, the increase of malarial fever always shows a correlation with the increase of anopheles mosquitoes, and a speedy decline of the disease always follow a great reduction of the number of anopheles Once this point is grasped, it will be seen that anti-malarial measures directed against mosquitoes to be effective must be carried out during that period of the year when anopheles are active in transmitting infection, and at other times efforts directed against mosquitoes will be fruitless. Hence we have to consider the condition of land surfaces and the existence of mosquito-breeding places, especially small collection of water, during the monsoon months, and we must concentrate our effort upon reducing the output of insects at this period. In a low-lying country, such as Bengal, where the land surface has very little fall and where there is a heavy rainfall it is an exceedingly difficult task to diminish the output of mosquitoes by drainage. On the other hand, provided we can obtain a sufficient supply of water there should be no great difficulty in converting the dangerous small pools into collections of water sufficiently large as to cease to be a danger. This is the measure that I propose should be adopted experimentally in consultation with the Irrigation Department in all areas in which conditions will allow. And for this urpose I have obtained a list of irrigation sluices I am informed that in the past very little use has been made of these sluices to provide a supply of water, but in consultation with the Irrigation Department I am hopeful that steps may be taken to utilise them during the present year. I have already arranged for an examination of the spleen indices of the villages served by these sluices. And it will be possible by watching the results of letting in water during the flood season to carry out a series of useful experiments at a comparatively small cost. In addition to this, I am hopeful of being able in the early future to make proposals for the carrying out of one or more larger scale experiments on the lines just indicated.

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